Appendix A. Additional and Supporting Figures for Section 3.1.3(HYSPLIT Trajectories)

Site-specific and matrix backward trajectories were calculated from the Las Vegas Valley on June 22, 2020, and are shown in **Figures A-1 and A-2** (see Section 3.1.3 for more details on HYSPLIT and the back trajectories calculated). The hour of 20:00 UTC (i.e., 12:00 p.m. local standard time) was chosen as the model starting time because it is the average time of peak ozone of the Paul Meyer, Walter Johnson, and Joe Neal sites on June 22. These trajectories showed air circling in the Las Vegas Valley for most of the morning, but were inconclusive to either the Arizona or Ivanpah fires. These trajectories do not adversely affect our conceptual model because the Arizona fires brought ozone precursors into the air the night before June 22. The air circling through the Las Vegas Valley in the presence of additional anthropogenic emissions and sunlight (the next day) would cause increased ozone production.

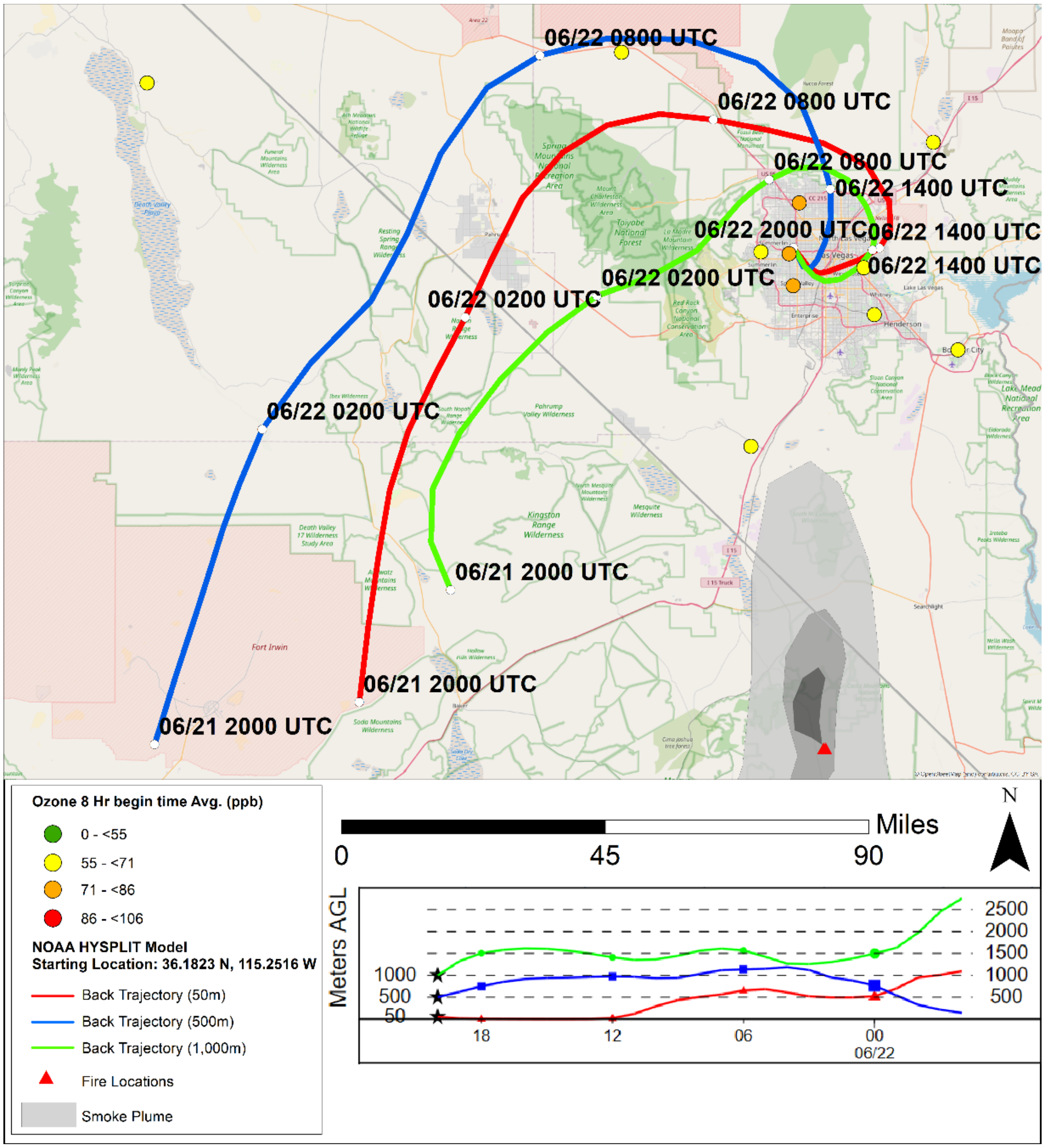

Figure A-1. 24-hour HYSPLIT back trajectories with smoke from the Las Vegas Valley, ending on June 22, 2020. NAM 12 km back trajectories are shown for 50 m, 500 m, and 1,000 m above ground level. Smoke plume is HMS smoke from June 22.

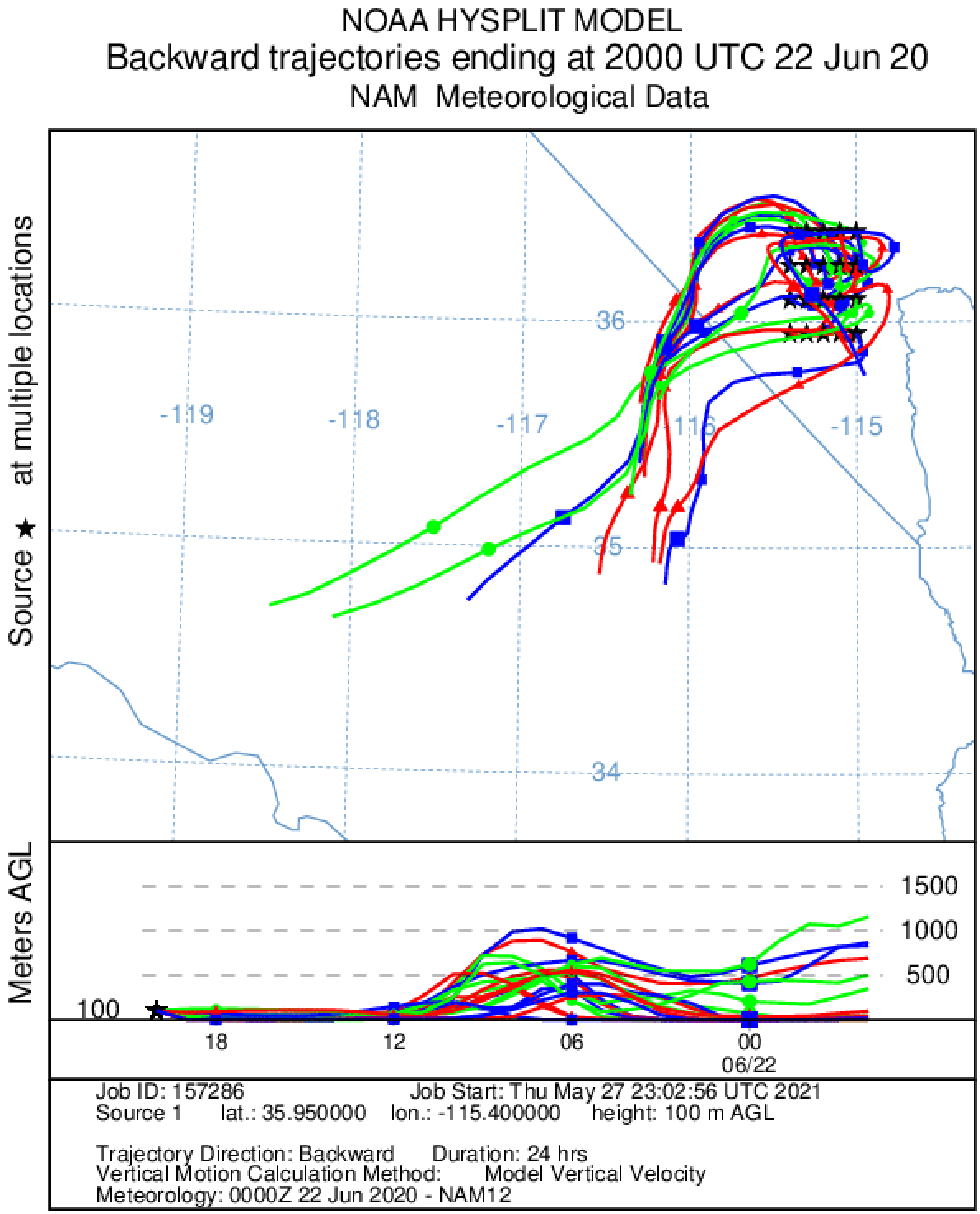

Figure A-2. HYSPLIT back trajectory matrix. A 24-hour, NAM 12 km back trajectory matrix was initiated on June 22 at 20:00 UTC (12:00 p.m. Local Time) from Las Vegas Valley at 100 m above ground level. The approximate area of the Ivanpah Fire is indicated by the red star.

Appendix B. Supporting Figures and Documents for Section 3.1.4 (Media Coverage and Ground Images)

4/23/2021 The Bush Fire is now the 5th largest in Arizona's history - CNN

The Bush Fire is now the 5th largest in Arizona's history as firefighters battle multiple blazes

By Joe Sutton and Hollie Silverman, CNN

Updated 3:58 AM ET, Tue June 23, 2020

The Bush fire has burned more than 186,000 acres in Arizona in the last ten days.

(CNN) — Firefighters are battling multiple blazes throughout Arizona this week including the Bush Fire, which is now the fifth largest in the state's history.

Fueled by hot, dry weather and tall grass, the human-caused Bush Fire has torn through 186,000 acres northeast of Phoenix, according to the Inciweb Incident Report.

Since the fire started ten days ago, 587 total resources have been deployed including 30 engines, three bulldozers, 18 water tenders and eight helicopters, the incident report said.

https://www.cnn.com/2020/06/23/us/arizona-bush-fire-tuesday/index.html 1/5

Figure B-1. CNN article published on June 23, 2020, entitled "The Bush Fire is now the 5th largest in Arizona's history as firefighters battle multiple blazes."

NWS Phoenix
@NWSPhoenix

The #BushFireTontoNF has now burned ~174,000 acres. The 5th largest in AZ history. You've seen the maps. You've seen the satellite images...but just what does that size look like?

For perspective, here's is a representation of the fire size from 6/20 placed over #Phoenix. #azwx

10:37 AM · Jun 21, 2020

138 5 Share this Tweet

CNN US LIVE TV

Residents and visitors near Apache Lake are in "Go" evacuation notice while nearby communities have been put on notice to be prepared for evacuations.

Roads have been closed and restriction have been put in place around the Tonto National Forest by the Gila County Sheriff's Office.

Firefighters achieved 61% containment as of late Monday night but there are still thousands of acres of flames to battle.

Figure B-1 (Cont.). CNN article published on June 23, 2020, entitled "The Bush Fire is now the 5th largest in Arizona's history as firefighters battle multiple blazes."

CNN US LIVE TV

The Bighorn Fire has been burning in Arizona, where at least 10 fires are burning.

At least seven fires continue to burn throughout the state of Arizona.

The state has already burned three times the amount of acres than 2019 year to date, Arizona Forestry Chief Steve Millert said during a press conference Monday.

The Bighorn Fire has burned more than 58,500 acres near Tucson while the Magnum Fire has burned nearly 70,000 acres in the northern part of the state.

Figure B-1 (Cont.). CNN article published on June 23, 2020, entitled "The Bush Fire is now the 5th largest in Arizona's history as firefighters battle multiple blazes."

NWS Tucson
@NWSTucson

Can you smell smoke? Here's a satellite view of all the smoke from fires across the southwest. Expect smoke to settle into parts of Tucson tonight through Tuesday morning. #azwx #azfire

US LIVE TV

8:06 PM · Jun 22, 2020

77 6 Share this Tweet

Thirty-three large fires have burned more than 544,000 acres nationwide, the National Interagency Fire Center said, with fire activity continuing in the Southwest over the weekend. Arizona saw the most acres burned, followed by Alaska and New Mexico, NIFC said.

Search CNN...

US

World

Politics

Business

Opinion

Health

Figure B-1 (Cont.). CNN article published on June 23, 2020, entitled "The Bush Fire is now the 5th largest in Arizona's history as firefighters battle multiple blazes."

4/23/2021 The Bush Fire is now the 5th largest in Arizona's history - CNN

NWS Tucson
@NWSTucson

Can you smell smoke? Here's a satellite view of all the smoke from fires across the southwest. Expect smoke to settle into parts of Tucson tonight through Tuesday morning. #azwx #azfire

CNN US LIVE TV

8:06 PM · Jun 22, 2020

77 6 Share this Tweet

Thirty-three large fires have burned more than 544,000 acres nationwide, the National Interagency Fire Center said, with fire activity continuing in the Southwest over the weekend. Arizona saw the most acres burned, followed by Alaska and New Mexico, NIFC said.

Search CNN...

US

World

Politics

Business

Opinion

Health

https://www.cnn.com/2020/06/23/us/arizona-bush-fire-tuesday/index.html 4/5

Figure B-1 (Cont.). CNN article published on June 23, 2020, entitled "The Bush Fire is now the 5th largest in Arizona's history as firefighters battle multiple blazes."

NEWS RELEASE

FOR IMMEDIATE RELEASE

Daniel R. Munsey
Fire Chief / Fire Warden

DATE: ***June 23, 2020***
CONTACT: ***Mike McClintock, Battalion Chief / Public Information Officer***
MMcClintock@sbcfire.org

Crews Assist National Park Service on 1,000 acre "Ivanpah Fire"

Date/Time: Wednesday, June 23, 2020
Location: Mojave National Preserve
Incident: Vegetation Fire

Summary: On 6/23/2020 San Bernardino County Fire crews were dispatched to assist the National Park Service (NPS) on a vegetation fire in the Lanfair Valley area of the Mojave National Preserve.

ME32, WT32 & Battalion 138 assisted the NPS & Bureau of Land Management (BLM) with structure defense of historic ranches & dip-site operations for helicopters. Some of the ranches date back to the 1800s and hold rich history. The closest water source was approximately one hour from the fire, making continuous water supply a challenge. Crews continued to keep the dip site full to allow helicopters to make drops quickly to slow the fires progress.

#SBCoFD remained on-scene for multiple hours until fire activity decreased, and the structure threat was mitigated. The fire burned approximately 1,000 acres of preserve land. Crews from NPS & BLM stayed on scene for multiple days working on mop-up operations and containment. The preserve spans more than 1.5 million acres in San Bernardino County & hosts Joshua Tree forests, sprawling view and historical sites.

###

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157 West Fifth St., 2nd Floor, San Bernardino, Ca. 92415-0451

Figure B-2. News release reported by San Bernadino County on June 23, 2020, reporting the Ivanpah Fire.

Appendix C. Extended Emissions Analyses

To further investigate the contribution of emissions from the fires identified in this demonstration to regional smoke conditions on the day of the event, an extended analysis was performed for fires not identified in the initial Q/d in Section 3.2.1; these fires, the Bighorn, Bush, and Mangum fires, are included in the analysis. We refer to the resulting value calculated from additional fires as "Extended Q/d" to distinguish these results with the Q/d calculated in accordance with EPA guidance.

The total emissions from the fires were substantial on June 22 (**Table C-1**), June 21 (**Table C-2**), and June 20 (**Table C-3**). These extended analyses provide evidence that additional fires emitted ozone precursors in the days leading up to June 22, 2020, and that emissions from these fires and the Ivanpah Fire contributed to the wildfire smoke conditions in Clark County, NV, on June 22, 2020.

Table C-1. Daily growth, emissions, and Extended Q/d for the Ivanpah, Bighorn, Bush, and Mangum fires with potential smoke contribution on June 22, 2020. Growth was obtained from agency estimates available from the Incident Information System (InciWeb) or media reports. Column "E (Tons)" represents the sum of NO_x and Reactive VOC emissions. The aggregate Extended Q/d for all fires is 2.0 tons/km.

Fire Name	Area (Acres)	Daily Growth (Acres)	NO_x (Tons)	VOCs (Tons)	Reactive VOCs (Tons)	E (Tons)	Distance (Km)	Extended Q/d (Tons/km)	Fuel Loading	Fire Size Data Source
Ivanpah Fire	1,000	1,000	3.7	19.44	12	15	110	0.1	Creosote bush shrubland	https://www.fireweatheravalanche.org/wildfire/incident/119448/california/ivanpah-fire
Bighorn Fire	58,553	0	0	0	0	0	570	0.0	Paloverde shrubland	https://inciweb.nwcg.gov/incident/6741/
Bush Fire	186,848	762	1.59	8.35	5	7	440	0.0	Paloverde shrubland	https://inciweb.nwcg.gov/incident/6773/
Mangum Fire	71,043	1,766	21.89	788.89	473	495	255	1.9	Ponderosa pine-two needle pinyon-Utah juniper forest	https://inciweb.nwcg.gov/incident/6748/

Table C-2. Daily growth, emissions, and Extended Q/d for the Bighorn, Bush, and Mangum fires with potential smoke contribution on June 21, 2020. Growth was obtained from agency estimates available from the Incident Information System (InciWeb). Column "E (Tons)" represents the sum of NO_x and Reactive VOC emissions. The aggregate Extended Q/d for all fires is 3.3 tons/km.

Fire Name	Area (Acres)	Daily Growth (Acres)	NO_x (Tons)	VOCs (Tons)	Reactive VOCs (Tons)	E (Tons)	Distance (Km)	Extended Q/d (Tons/km)	Fuel Loading	Fire Size Data Source
Bighorn Fire	58,553	6,925	14.43	75.85	46	60	570	0.1	Paloverde shrubland	https://inciweb.nwcg.gov/incident/6741/
Bush Fire	186,086	1,555	3.24	17.03	10	13	440	0.0	Paloverde shrubland	https://inciweb.nwcg.gov/incident/6773/
Mangum Fire	69,277	2,983	36.98	1332.53	800	836	255	3.3	Ponderosa pine-two needle pinyon-Utah juniper forest	https://inciweb.nwcg.gov/incident/6748/

Table C-3. Daily growth, emissions, and Extended Q/d for the Bighorn, Bush, Mangum, and Ivanpah fires with potential smoke contribution on June 20, 2020. Growth was obtained from agency estimates available from the Incident Information System (InciWeb). Column "E (Tons)" represents the sum of NO_x and Reactive VOC emissions. The aggregate Extended Q/d for all fires is 2.1 tons/km.

Fire Name	Area (Acres)	Daily Growth (Acres)	NO_x (Tons)	VOCs (Tons)	Reactive VOCs (Tons)	E (Tons)	Distance (Km)	Extended Q/d (Tons/km)	Fuel Loading	Fire Size Data Source
Bighorn Fire	51,628	8,830	18.4	96.71	58	76	570	0.1	Paloverde shrubland	https://inciweb.nwcg.gov/incident/6741/
Bush Fire	184,531	10,134	21.12	110.99	67	88	440	0.3	Paloverde shrubland	https://inciweb.nwcg.gov/incident/6773/
Mangum Fire	66,294	1,785	22.13	797.37	478	501	255	2.0	Ponderosa pine-two needle pinyon-Utah juniper forest	https://inciweb.nwcg.gov/incident/6748/

Appendix D. Figures Supporting Section 3.2.3 (Satellite Retrievals of Pollutant Concentrations)

OMI retrievals of tropospheric NO_2 (**Figure D-1**) were examined. However, over areas of dense, visible smoke and near actively burning fires, where significant smoke is present in the troposphere, the measurements show only a slight increase in measured NO_2. Therefore, it was determined that NO_2 does not provide strong evidence for or against smoke impacts in Clark County.

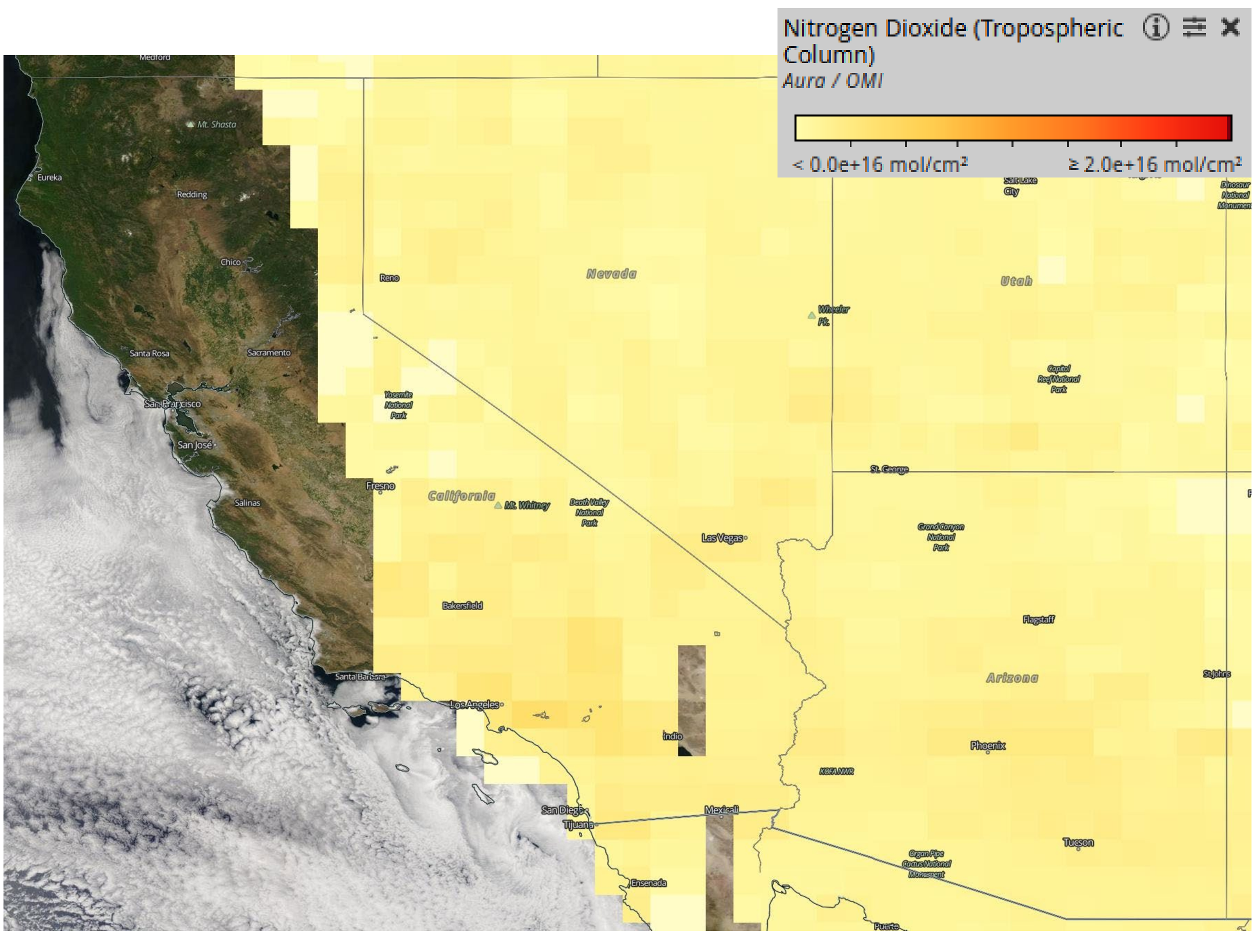


Figure D-1. OMI Aura NO_2 retrieval for the EE on June 22, 2020.

Appendix E. Figures and Tables Supporting Section 3.3.2 (Matching Day Analysis)

A substantial number of wildfires occurred in the southwestern United States in 2017. There is evidence that wildfires could have impacted ozone concentrations in Clark County on June 16, 2017, though this has not been officially classified as a day that was influenced by wildfire emissions. A substantial number of fires were burning in the surrounding region. **Figure E-1** and **Figure E-2** show air in the days preceding June 16, 2017, passing through the San Joaquin Valley, a region with several active wildfires on June 15 and June 16, on its path towards Clark County. This further emphasizes that an ozone exceedance on a day with meteorological conditions similar to June 22, 2020, likely occurred due to an outside source of ozone production.

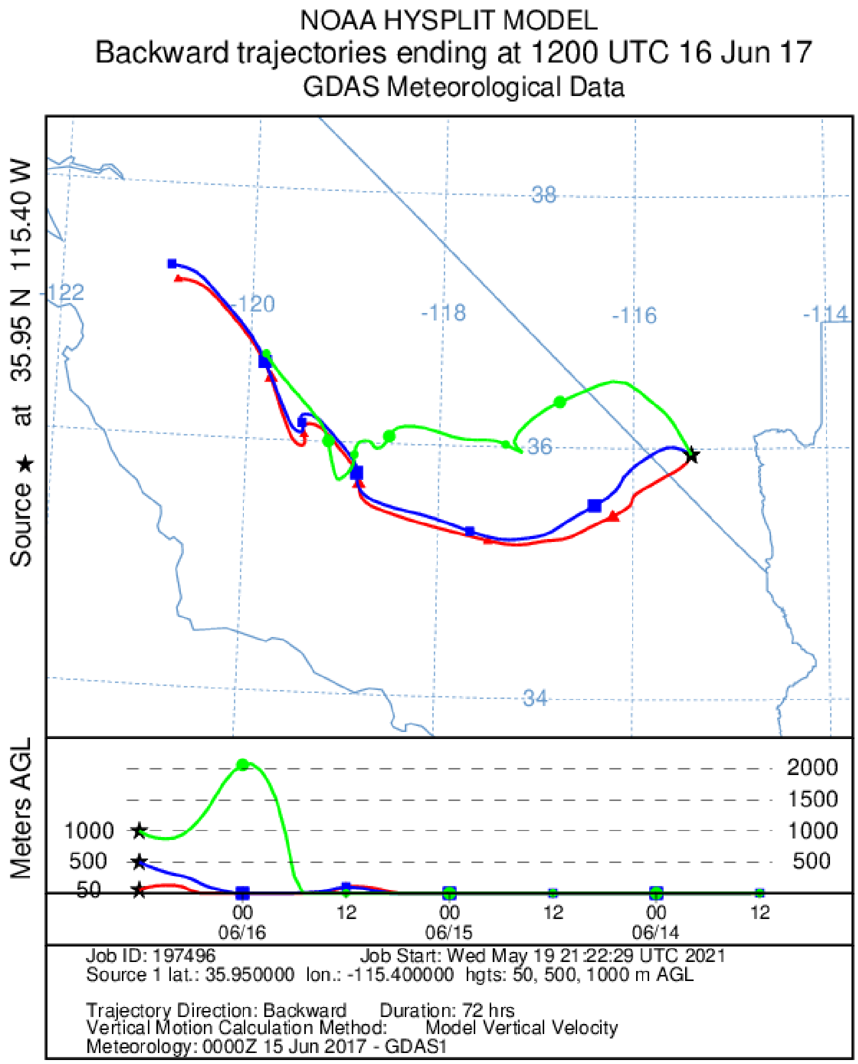


Figure E-1. 72-hour HYSPLIT back trajectories from Las Vegas Valley, ending on June 16, 2017. Trajectories include 50 m (red), 500 m (blue), and 1000 m (green).

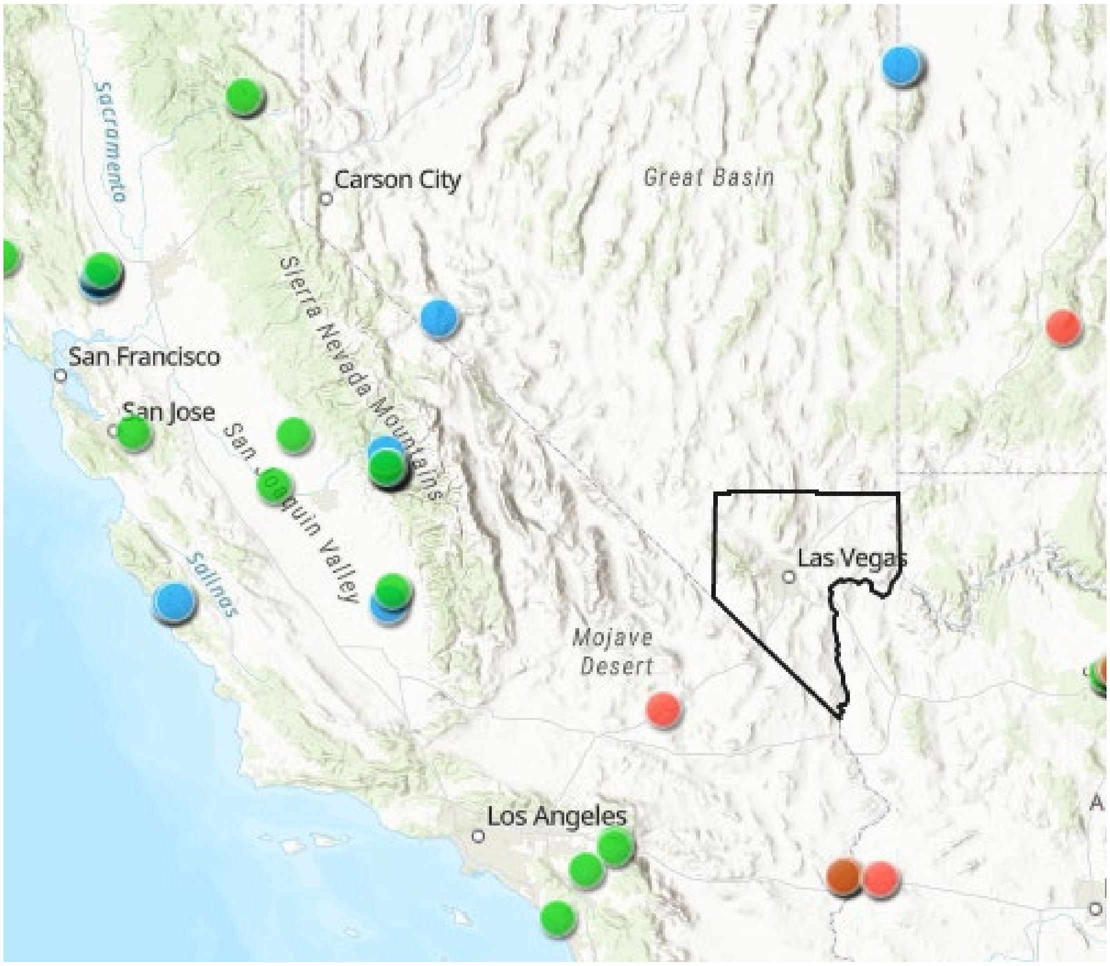


Figure E-2. NOAA HMS fire product map showing fires on June 14, 2017 (blue), June 15, 2017, (green) and June 16, 2017 (red). Clark County is outlined in black. https://www.ospo.noaa.gov/Products/land/hms.html

Identification of matching (meteorologically similar) days includes a comparison of meteorology maps between June 22 and each date subset from candidate matching days. The surface maps for June 22, 2020, and each date listed in Table 3-14 all show a surface low pressure system directly over Clark County, and most dates have an area of high pressure directly to the east. Surface maps for June 22, 2020, and each date in Table 3-14 are shown in Figure E-3 through Figure E-13. Though there is more variability in the upper-level maps, there is a consistent area of high pressure south of Clark County and a minimal pressure gradient for all days. 500-mb maps for June 22, 2020, and each date in Table 3-14 are shown in Figure E-14 through Figure E-24.

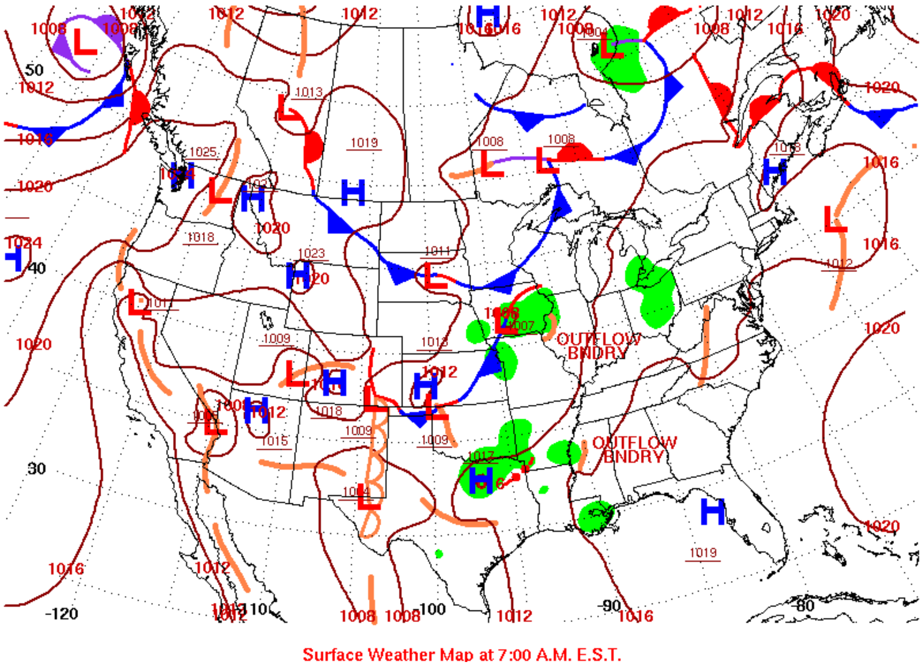


Figure E-3. Surface meteorology map on June 22, 2020 (the event date).

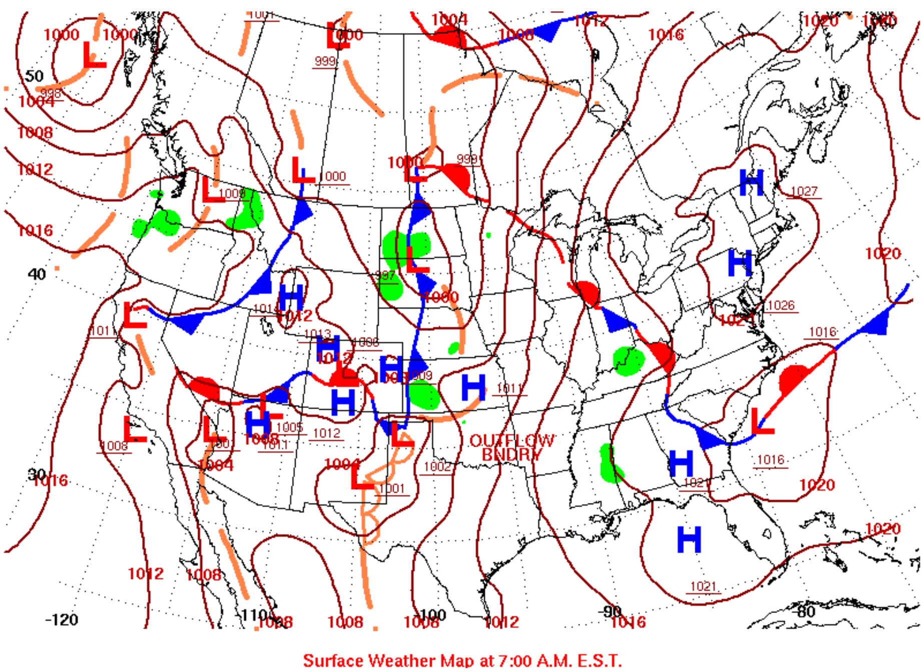


Figure E-4. Surface meteorology map on June 28, 2014.

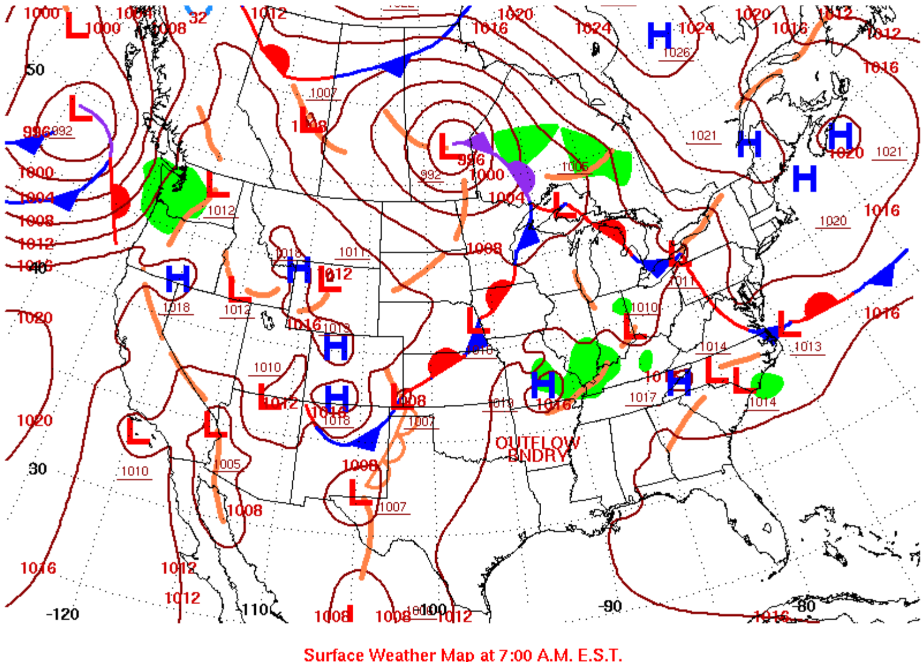


Figure E-5. Surface meteorology map on June 15, 2017.

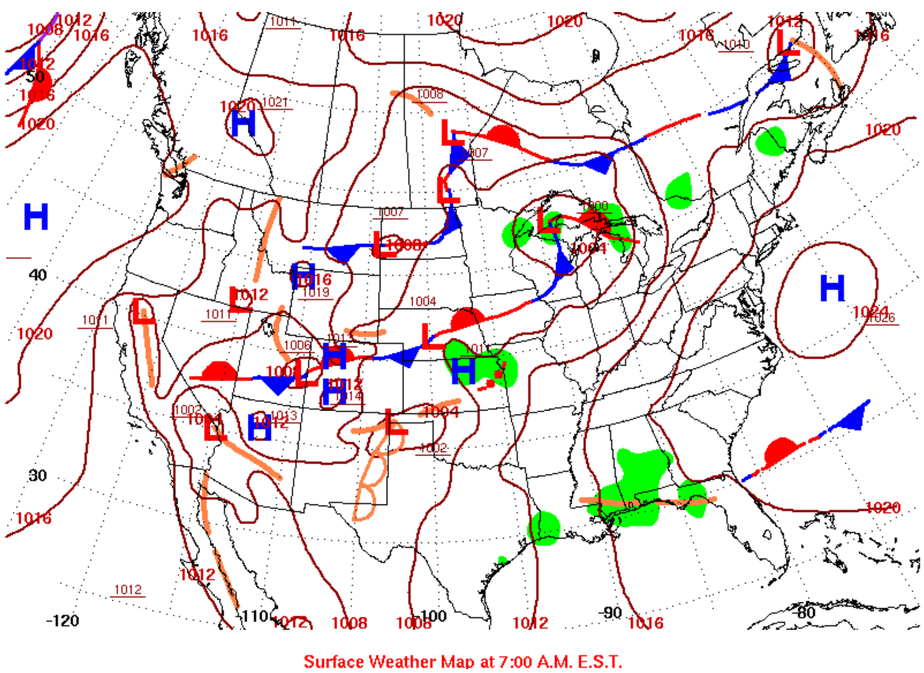


Figure E-6. Surface meteorology map on June 29, 2017.

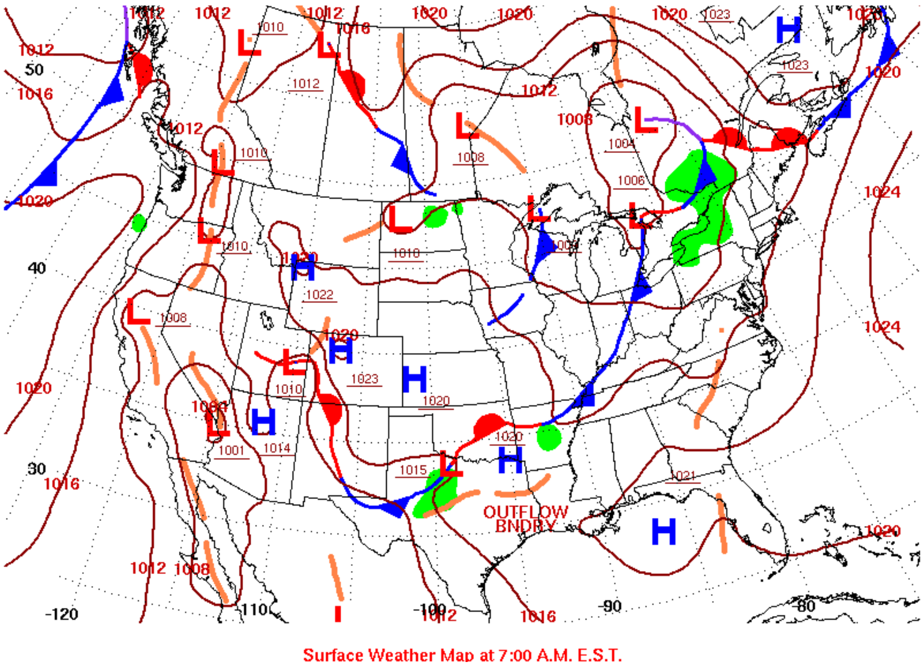


Figure E-7. Surface meteorology map on July 1, 2017.

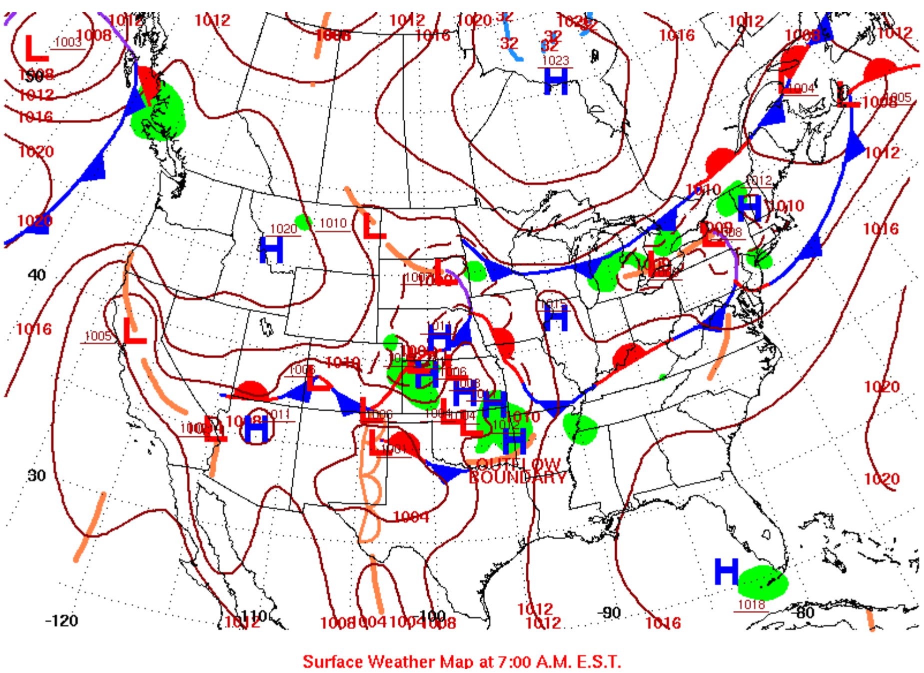


Figure E-8. Surface meteorology map on June 24, 2018.

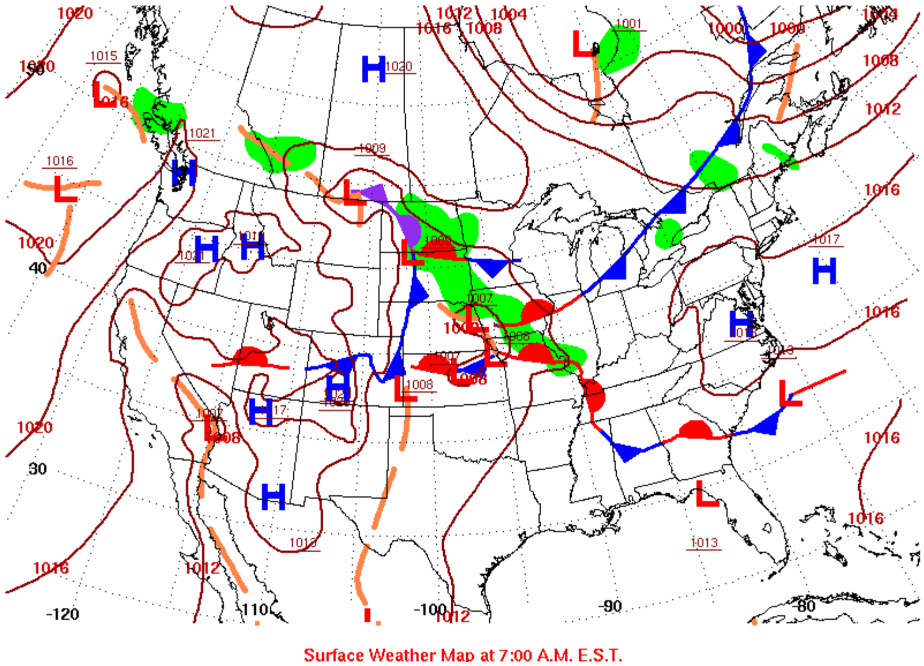


Figure E-9. Surface meteorology map on August 12, 2019.

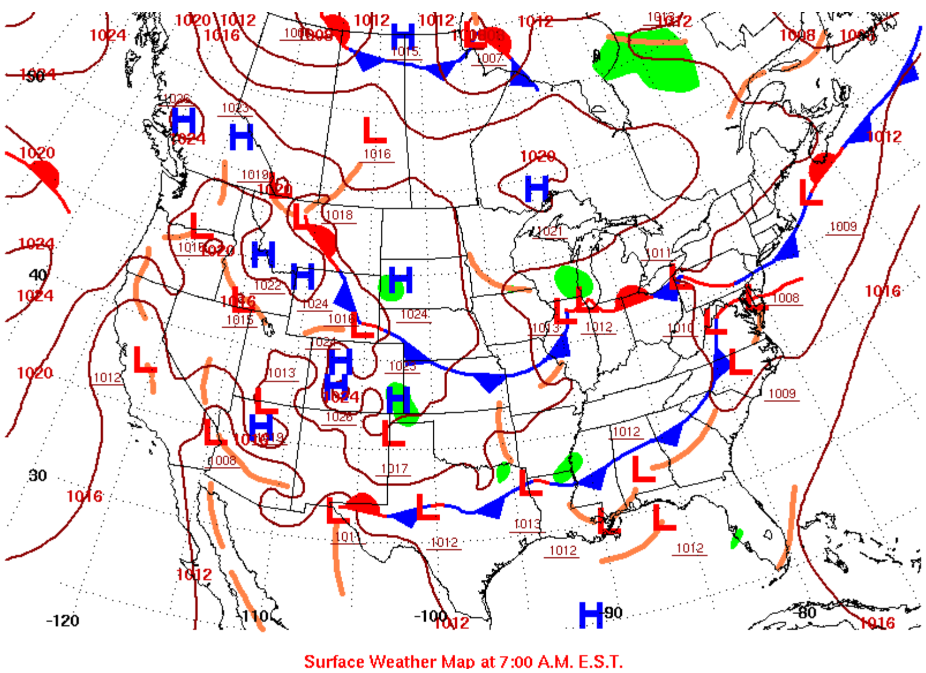


Figure E-10. Surface meteorology map on August 14, 2019

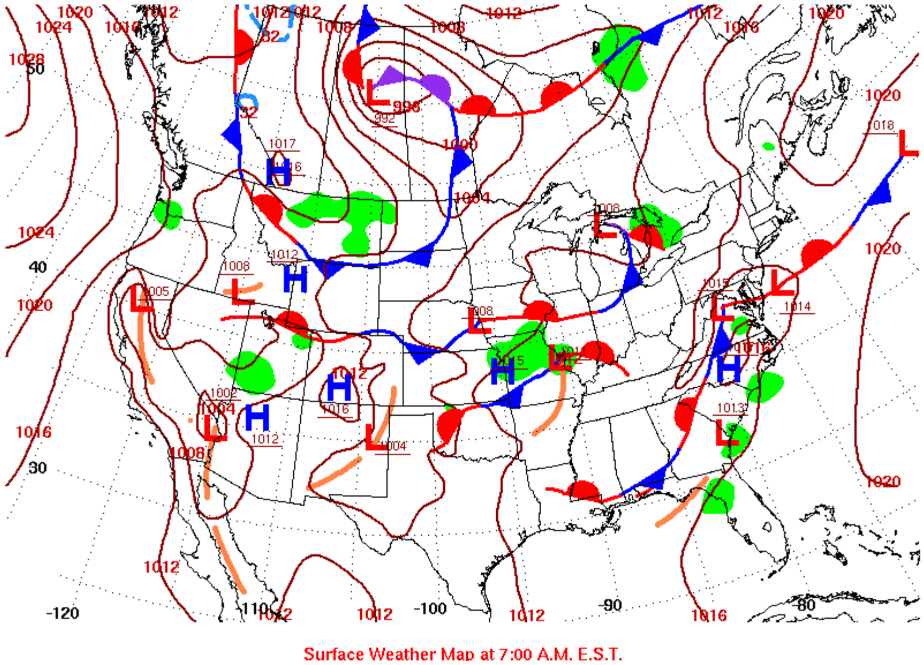


Figure E-11. Surface meteorology map on August 17, 2019.

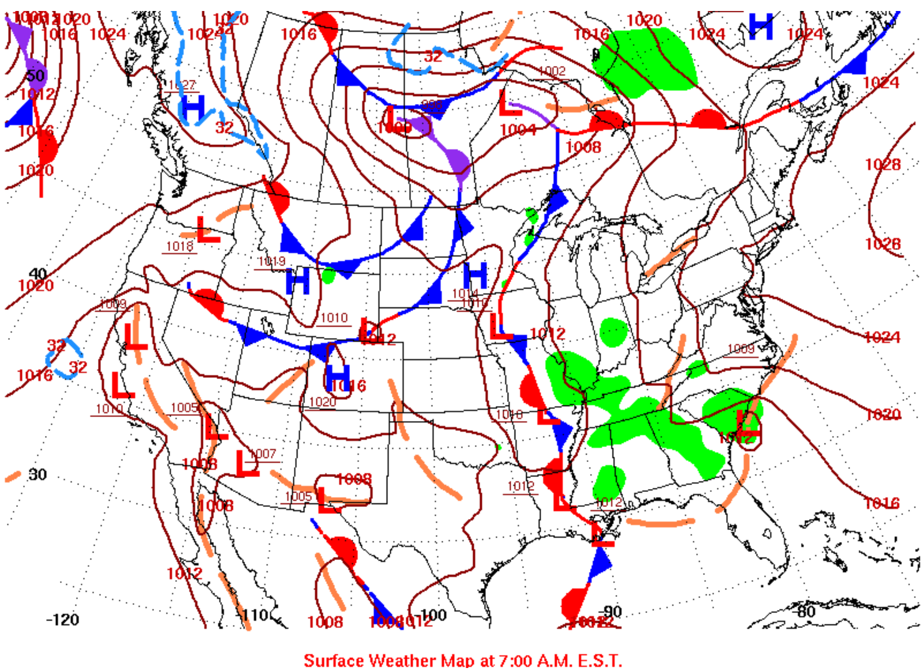


Figure E-12. Surface meteorology map on May 27, 2020.

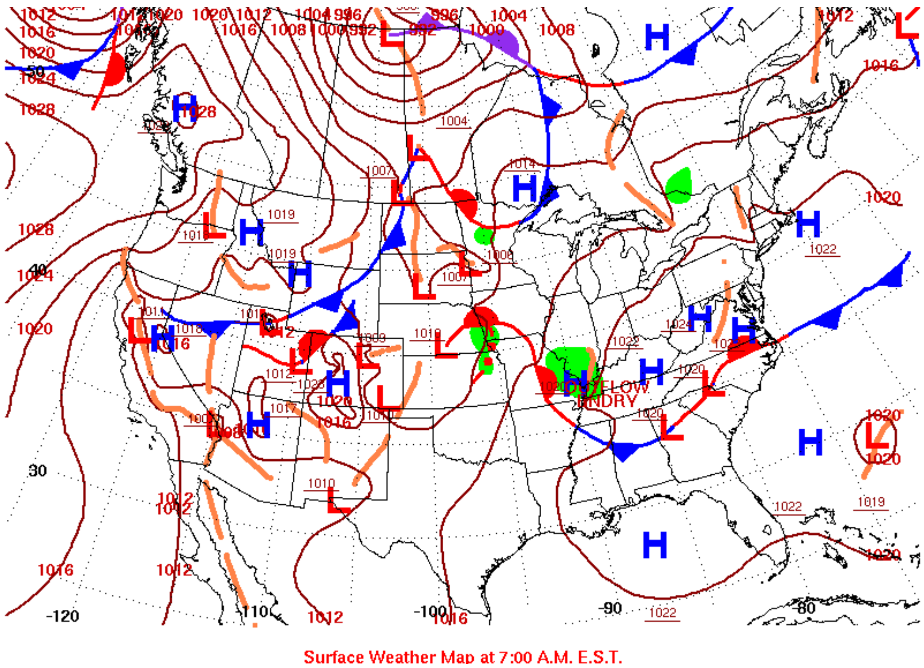


Figure E-13. Surface meteorology map on August 9, 2020.

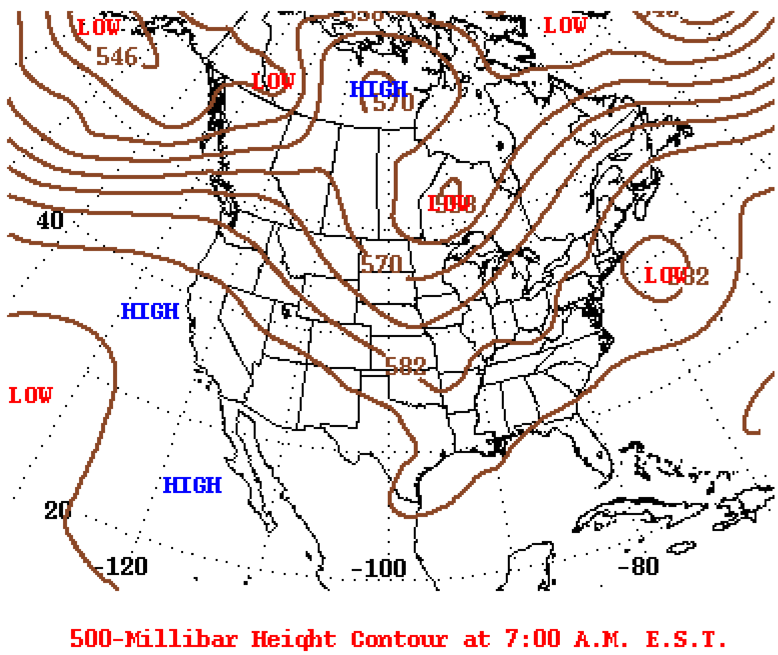


Figure E-14. 500 mb meteorology map on June 22, 2020 (the event date).

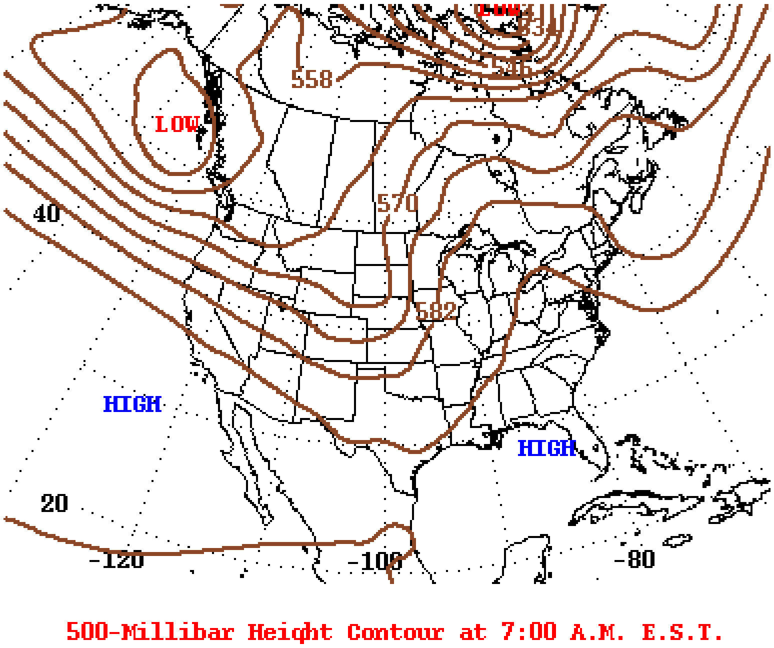


Figure E-15. 500-mb meteorology map on June 28, 2014.

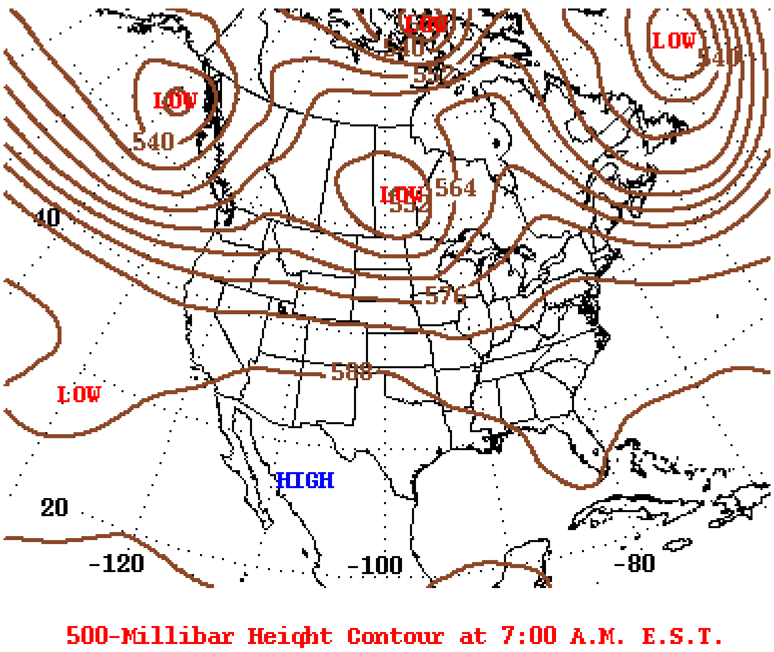
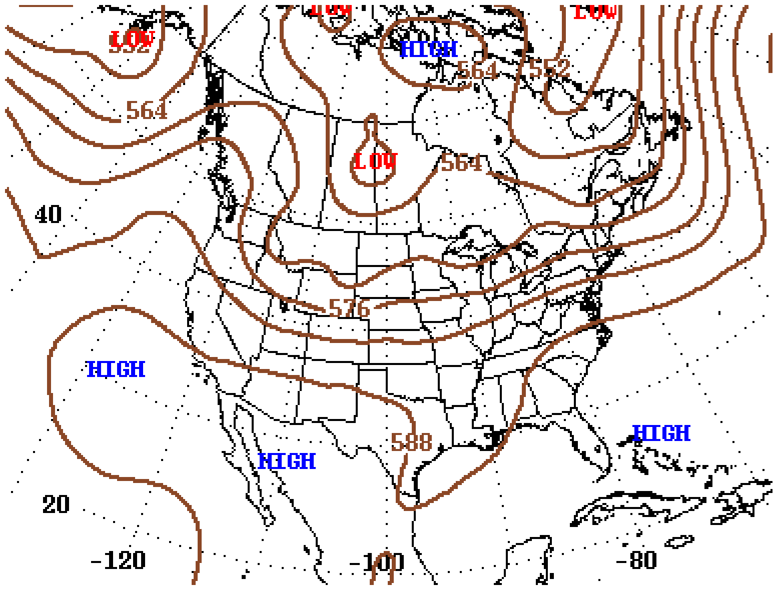
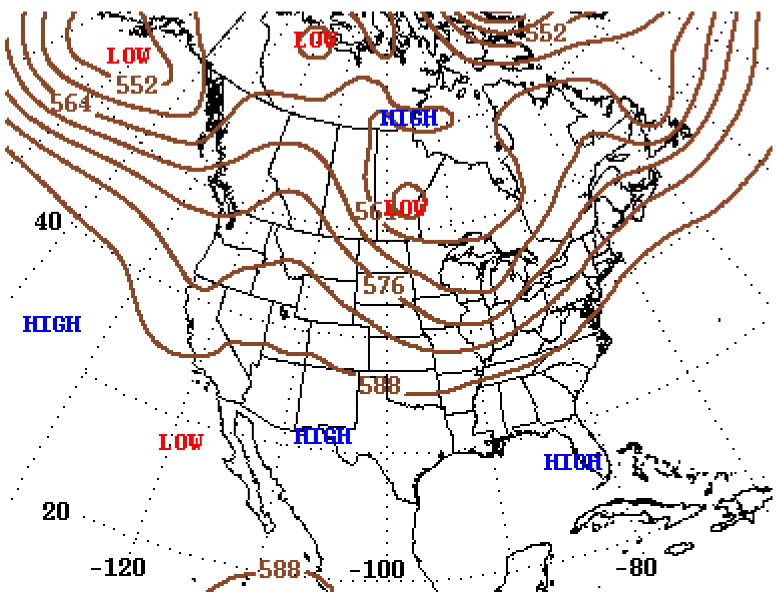


Figure E-16. 500-mb meteorology map on June 15, 2017.



500-Millibar Height Contour at 7:00 A.M. E.S.T.

Figure E-17. 500-mb meteorology map on June 29, 2017.



500-Millibar Height Contour at 7:00 A.M. E.S.T.

Figure E-18. 500-mb meteorology map on July 1, 2017.

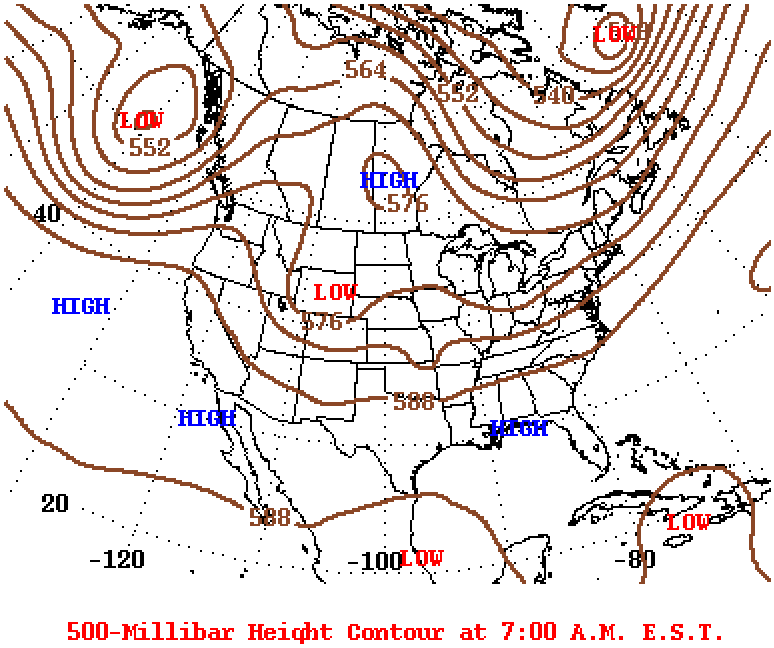


Figure E-19. 500-mb meteorology map on June 24, 2018.

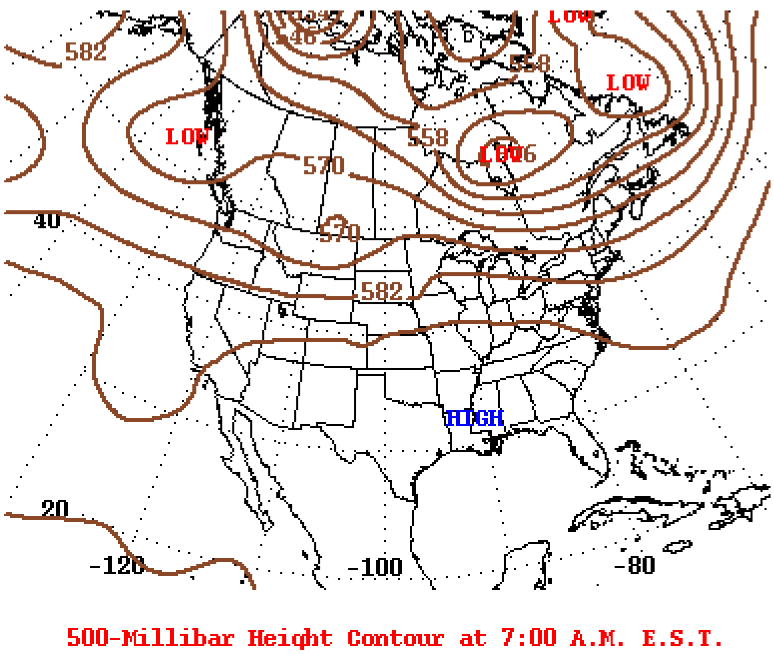


Figure E-20. 500-mb meteorology map on August 12, 2019.

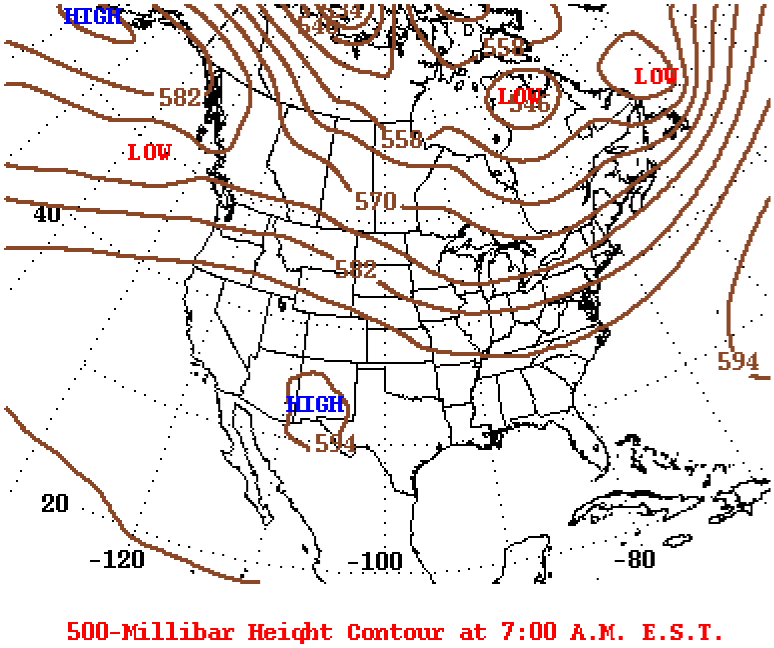


Figure E-21. 500-mb meteorology map on August 14, 2019.

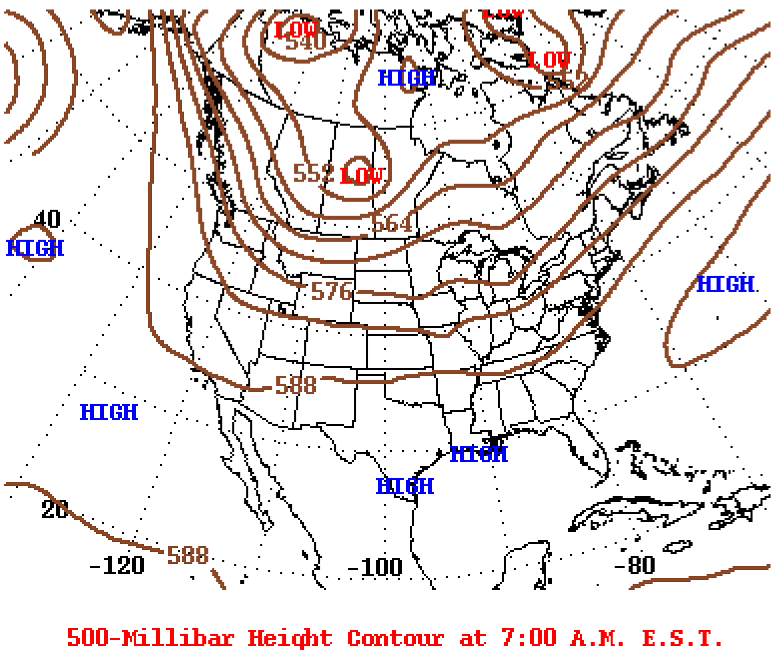


Figure E-22. 500-mb meteorology map on August 17, 2019.

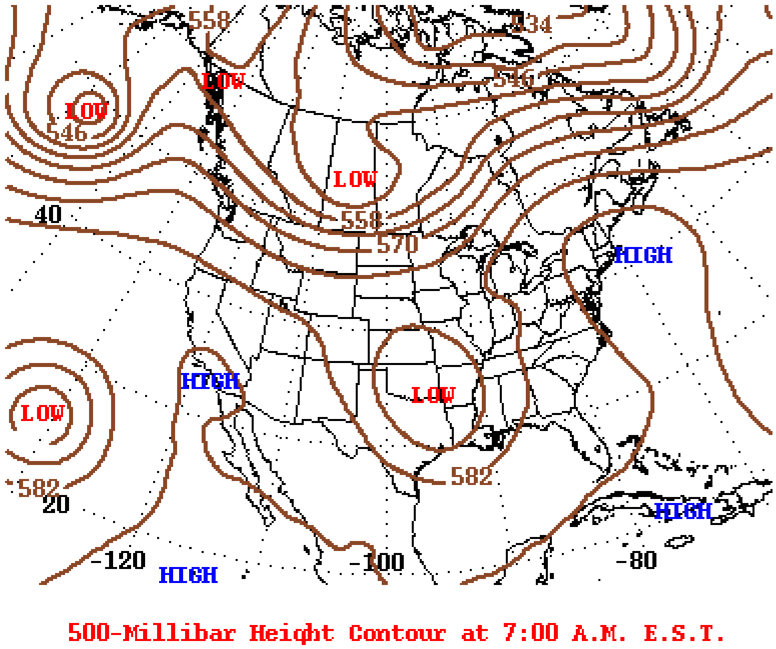


Figure E-23. 500-mb meteorology map on May 27, 2020.

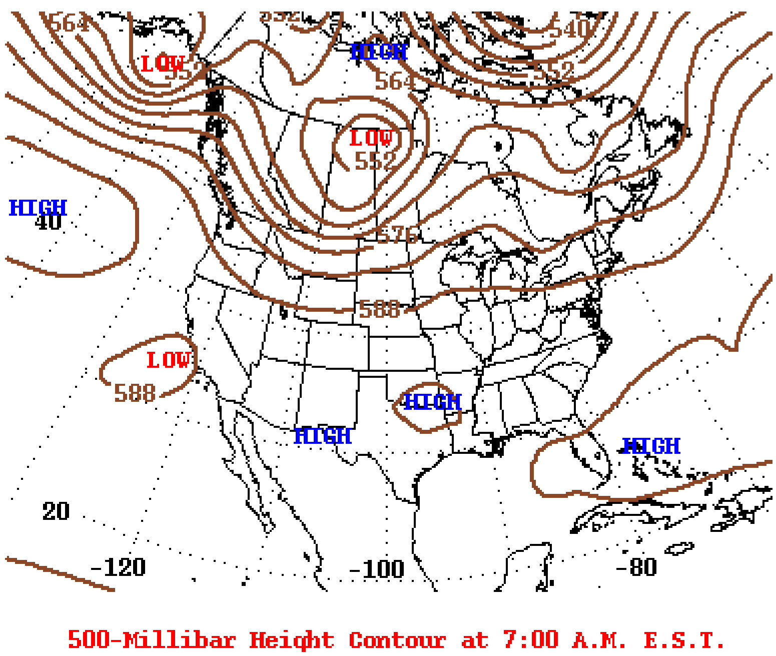


Figure E-24. 500-mb meteorology map on August 9, 2020.

Appendix F. GAM Residual Histograms and Scatter Plots from Concurred Exceptional Event Demonstrations

The following are GAM residual histograms and scatter plots from the concurred Arizona Department of Environmental Quality demonstration (Arizona Department of Environmental Quality 2016) and the submitted Texas Commission on Environmental Quality demonstration (Texas Commission on Environmental Quality 2021) for comparison with our GAM residual analysis. The figures in this Appendix show the good residual results from concurred and currently submitted exceptional events demonstrations to which we compared our results. Based on this comparison, we suggest that our GAM results show a well-fit, unbiased model. A well-fit GAM model should show a normal distribution of residuals at all sites modeled (ADEQ example in **Figure F-1**) and show no pattern or bias between GAM residuals and predicted values (TCEQ example in **Figure F-2**). These figures compare well with our GAM results in Section 3.3.3 of the main report.

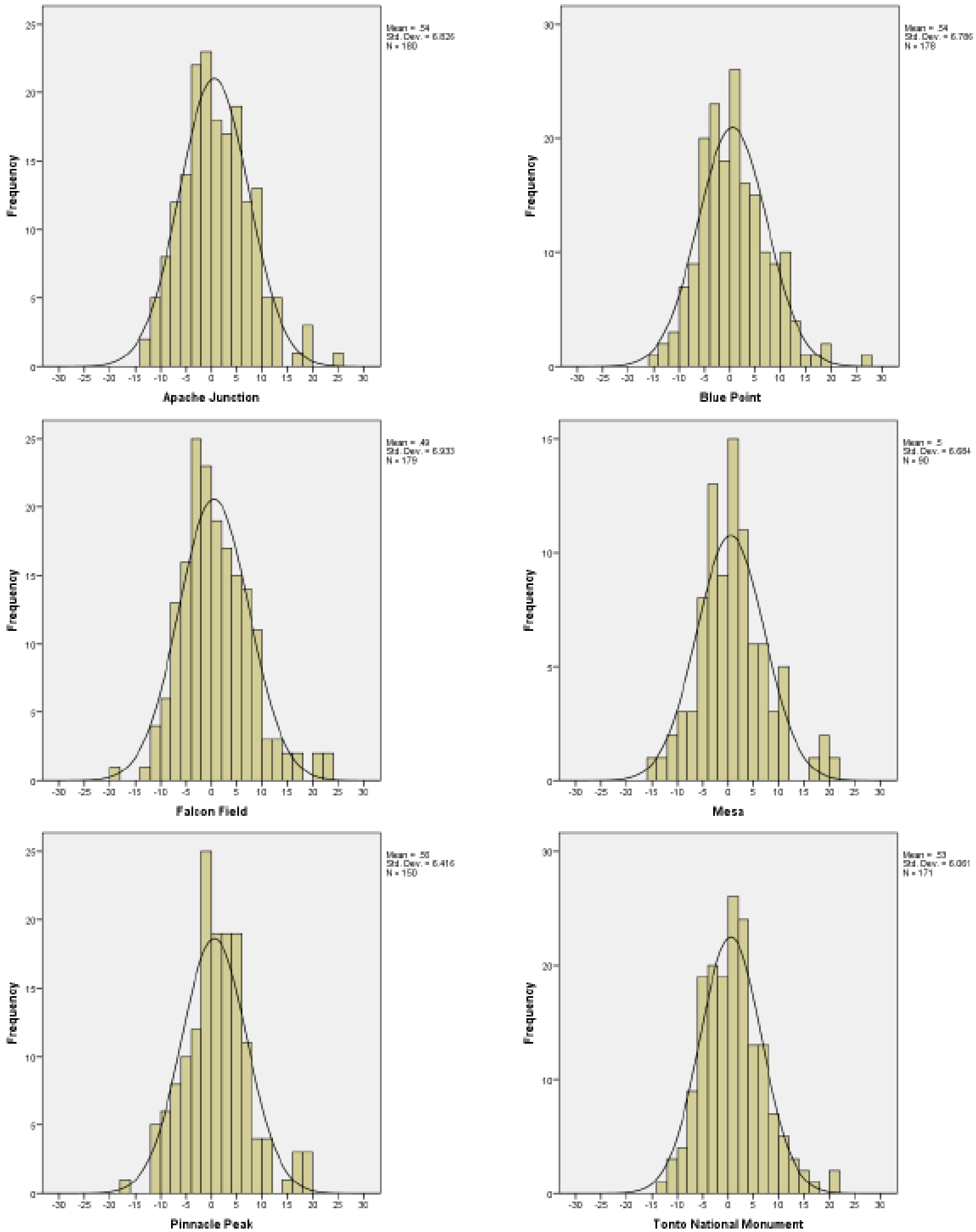


Figure F-1. Histograms of residuals results at each monitoring site from the Arizona DEQ GAM Analysis (Arizona Department of Environmental Quality 2016).

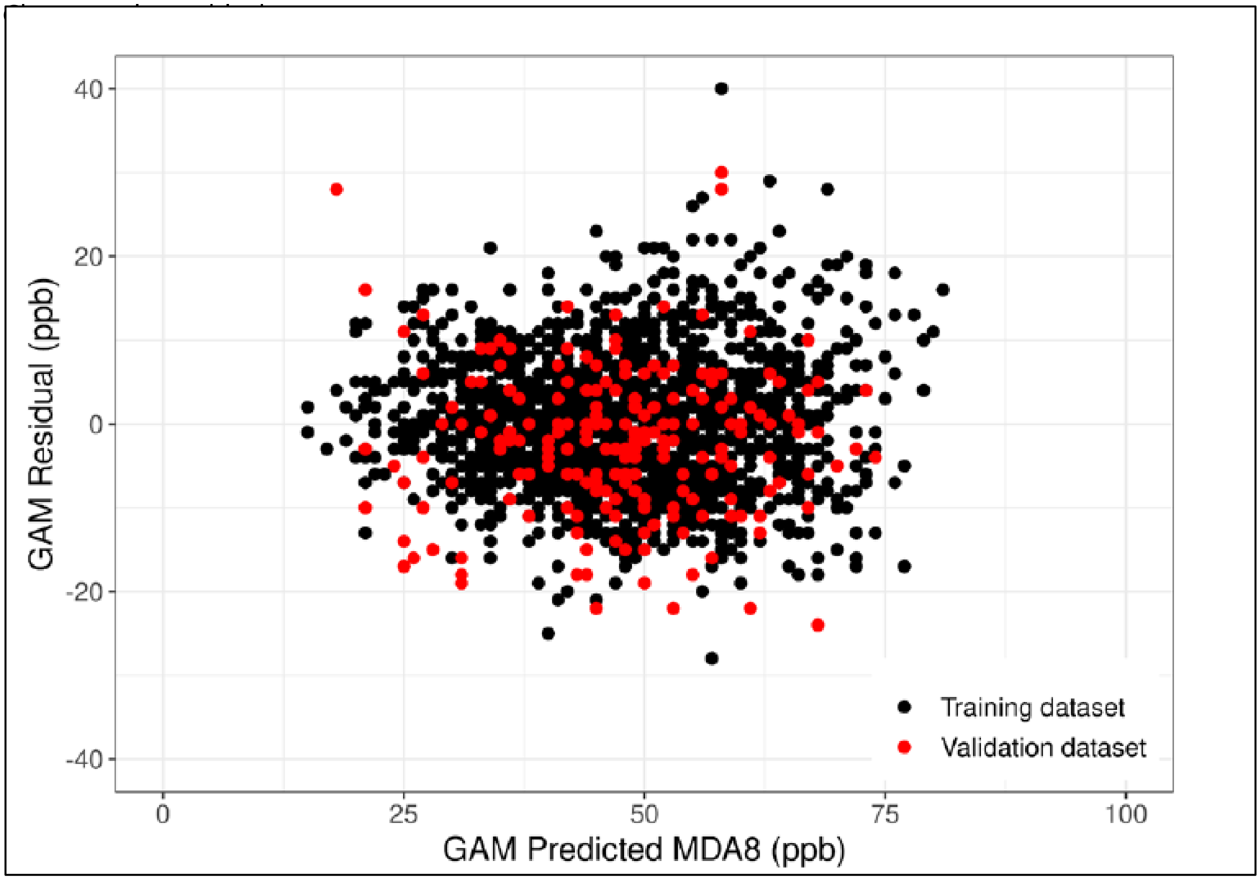


Figure F-2. Scatter plot of GAM residuals (observed – GAM predicted MDA8 ozone) vs. GAM predicted MDA8 ozone from the TCEQ submitted GAM analysis. Training data is shown in black and validation data is shown in red (Texas Commission on Environmental Quality 2021).

References

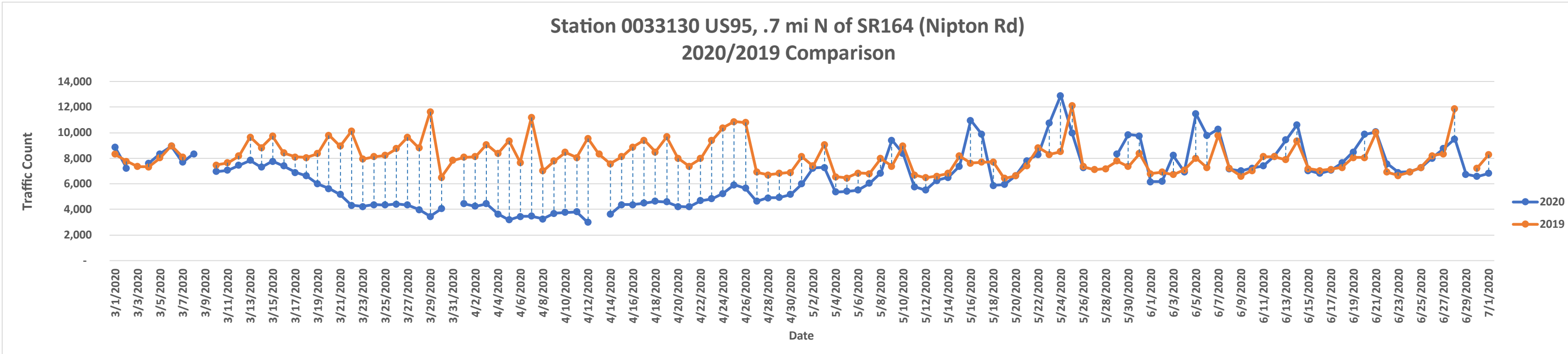
Arizona Department of Environmental Quality (2016) State of Arizona exceptional event documentation for wildfire-caused ozone exceedances on June 20, 2015 in the Maricopa nonattainment area. Final report, September. Available at https://static.azdeq.gov/pn/1609_ee_report.pdf.

Texas Commission on Environmental Quality (2021) Dallas-Fort Worth area exceptional event demonstration for ozone on August 16, 17, and 21, 2020. April. Available at https://www.tceq.texas.gov/assets/public/airquality/airmod/docs/ozoneExceptionalEvent/2020-DFW-EE-Ozone.pdf.

Appendix G. Analysis of COVID Restrictions on Ozone

Mobile emission sources decreased throughout the U.S. during the mobility restrictions for the COVID-19 pandemic beginning in mid-March 2020. Because decreases in NOx emissions from these mobile sources could result in higher ozone concentrations, we evaluate the potential contribution and sensitivity of the COVID shutdown effects on ozone concentrations and MDA8 ozone on EE days. Ozone production has non-linear dependence on precursor emissions of NOx and VOCs and meteorological conditions. Changes in precursors also shift photochemical regimes. Thus, the effects of COVID-induced NOx emission changes on ozone are complex and uncertain (Kroll et al., 2020). Recent studies have found variable ozone responses during lockdowns across countries ranging from −2 to +10% (Venter et al., 2020). Park et al., 2020, found spatially disparate effects of higher ozone concentrations downwind of Los Angeles and lower concentrations in the western LA basin. To evaluate the potential influence of COVID shutdown precursor emission decreases on increases in MDA8 ozone, we compared May 2020 ozone to the historical climatology and compared the GAM residuals during May 2020 with those for the same historical record.

Based on 2017 emission inventories in Las Vegas, on-road mobile sources comprise 40% of NOx emissions, and total mobile (vehicle + aviation) emissions comprise 88% of total NOx emissions for a typical ozone season weekday (SIP Plan Revision, Clark County 2015). In contrast, only 11% of VOC emissions originate from on-road mobile sources. The effects of decreased mobility due to COVID restrictions has a significant effect on total NOx emissions, but minimal effect on VOC emissions. To determine the time period for these effects, we compared 2020 daily traffic count data from the Nevada Department of Transportation with that from 2019 at 10 monitoring sites (two examples in Figure G-1). On-road traffic activity was significantly reduced from mid-March through early June 2020 in Clark County compared with 2019. Although aviation activity remained lower than pre-pandemic levels for a longer duration of 2020, commercial aviation represents only 12% of NOx emissions in Clark County. Thus, the reduced aviation activity had a minimal influence on precursors available for ozone formation from mid-June 2020 onwards. Here we focus on May 2020, the first month of 2020 with EE days.



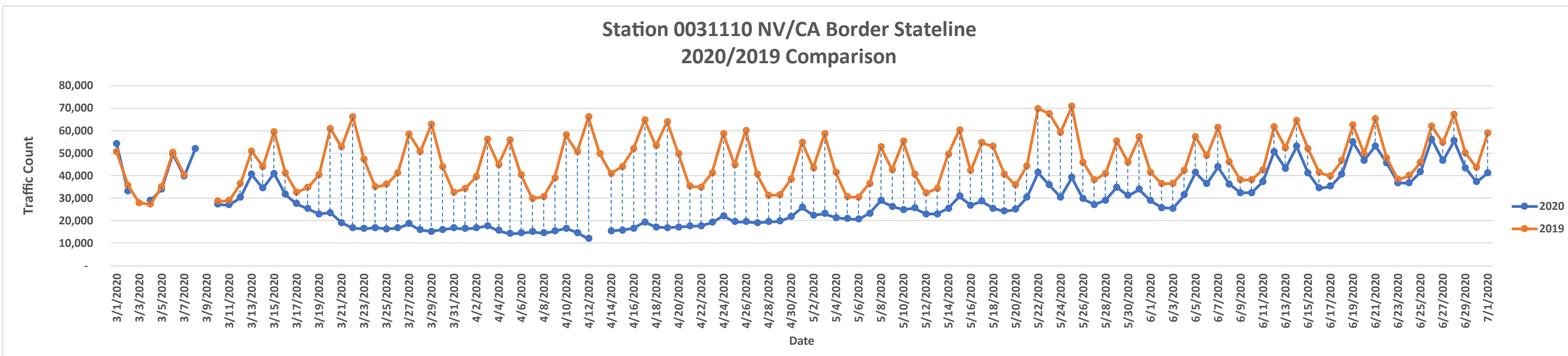
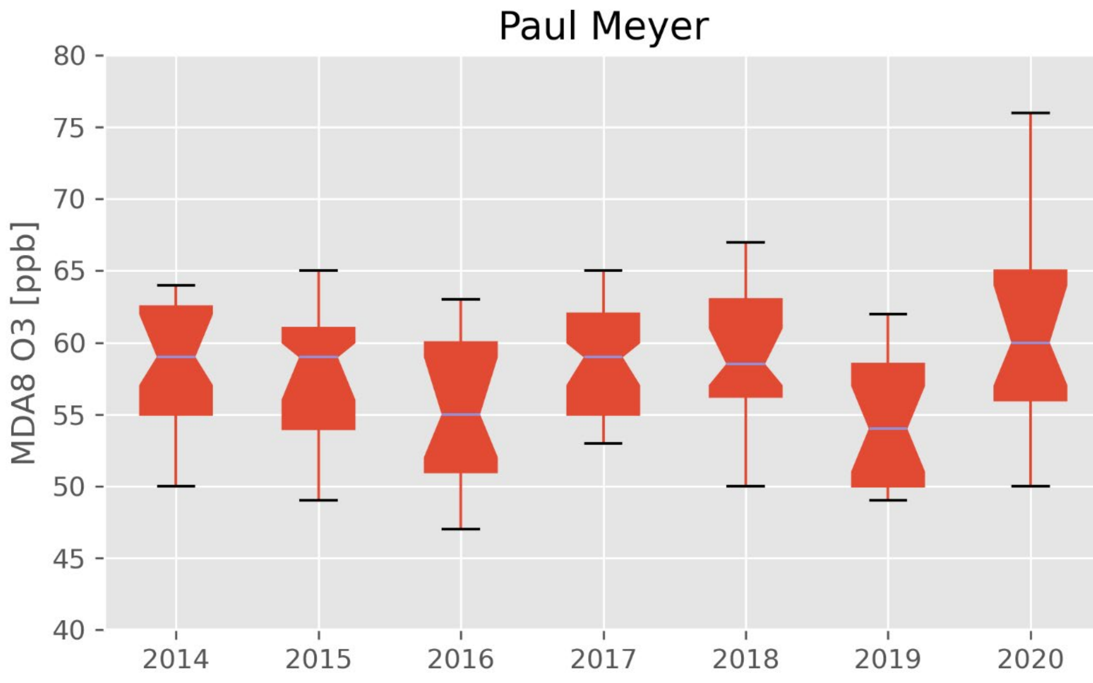


Figure G-1. Time series of 2020 and 2019 traffic counts at two stations: US95 south of Las Vegas (top) and the Nevada-California border west of Las Vegas (bottom). Data were provided by the Nevada Department of Transportation.

Two sub-analyses for the ozone comparison to historical climatology were performed. First, we compared the distribution of daily MDA8 ozone during May 2020 with those during each May in the previous 5 years. Across all EE sites, we found median 2020 MDA8 ozone was not statistically different than any of the previous 5 years. This is illustrated by the overlap in the 95th confidence intervals of the monthly medians from previous years and 2020 (**Figure G-2**). Furthermore, monthly median MDA8 ozone during May 2020 was not particularly high (<<65 ppb) at all sites despite the EE days. This indicates that the EE day exceedances were extreme episodes that did not affect the monthly median. Thus, the observations do not suggest a month-long high ozone effect due to COVID emission precursor changes. Second, we compared the historical distribution of daily MDA8 ozone during May with the observations during May 2020 (**Figure G-3**). Across all EE sites, MDA8 ozone on the exceedance days for a given site rank above the confidence interval of the historical daily median MDA8 ozone. Based on these sub-analyses, we conclude that although precursor NOx emissions decreased during May 2020 due to COVID restrictions, MDA8 ozone concentrations were not statistically higher than previous years, and the EE days cannot be attributed to a consistent month-long increase in ozone concentrations due to the COVID shutdown.

To evaluate the GAM model residuals during the COVID shutdown period, Figure 3-47 in Section 3.3.3 provides a more in-depth look at the most heavily affected months, April to May, 2020. The 95th confidence interval of the median GAM MDA8 residuals (shown by the notches in the box plots) overlap between 2020 and most other years (except 2015 and 2016). The May 2020 median residual with EE days (1.5 ppb) is lower than the typical GAM model uncertainty given by the range of confidence intervals for median residuals at comparable ozone concentrations (+2.9 to 5.3 ppb, Table 3-16 in Section 3.3.3). The median GAM residuals during May 2020 were within the typical GAM model error during the previous 5 years.

In summary, although mobile source precursor emissions of NOx decreased during April and May 2020 due to COVID shutdown restrictions, we did not observe statistically higher ozone, nor a higher residual in the GAM model, during May 2020. We find consistent evidence across analyses that the EE day ozone concentrations cannot be attributed to an increase in ozone concentrations associated with COVID shutdown periods.


Paul Meyer
MDA8 O3 [ppb]
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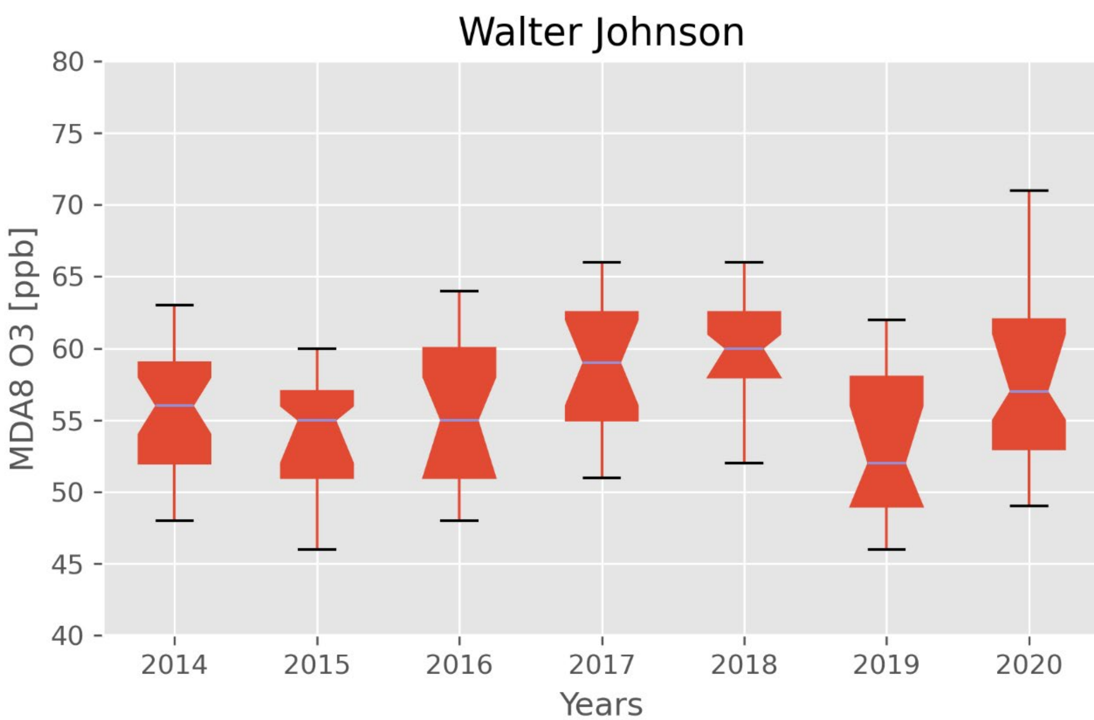
Walter Johnson
MDA8 O3 [ppb]
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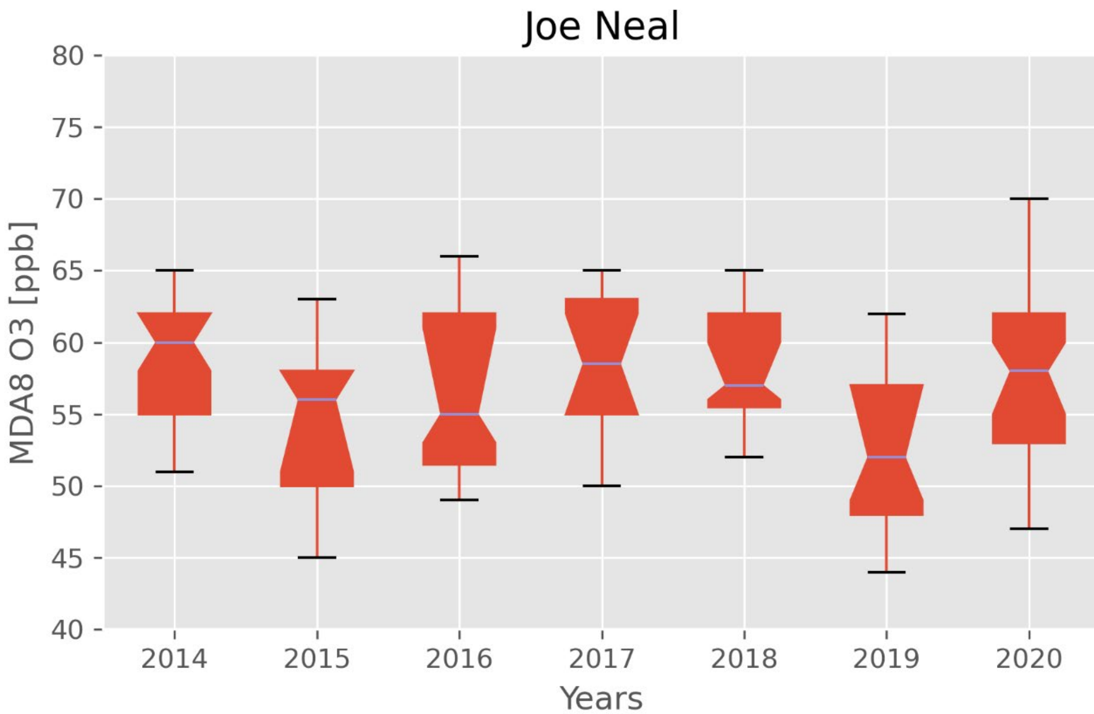
Joe Neal
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MDA8 O3 [ppb]
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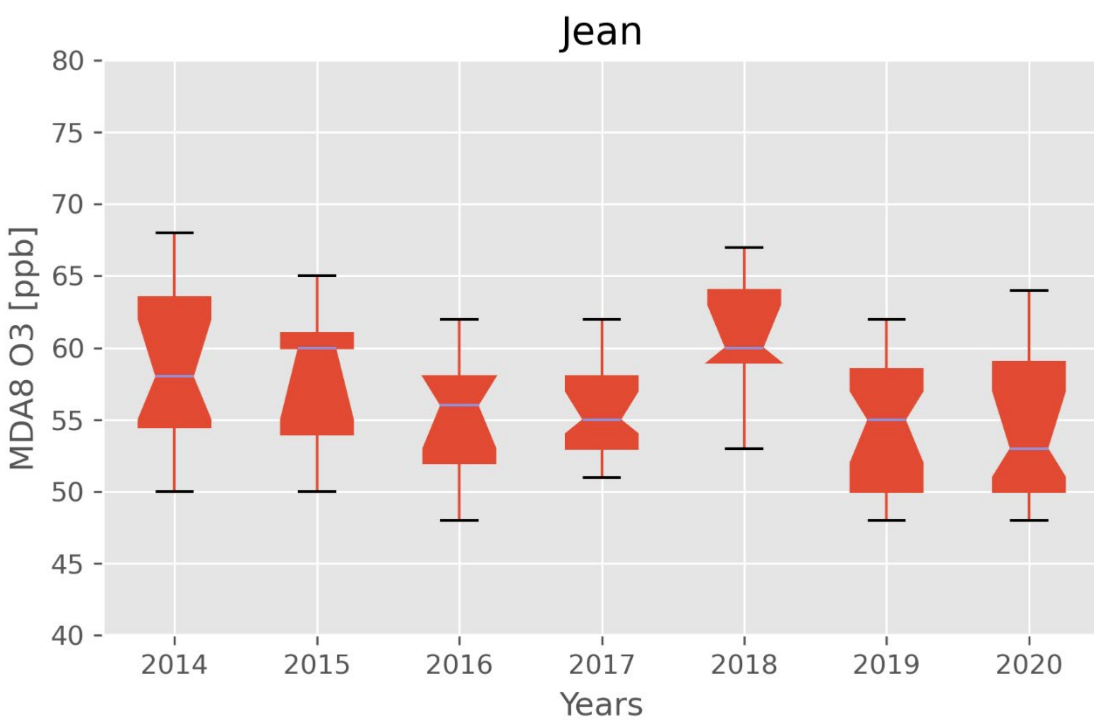
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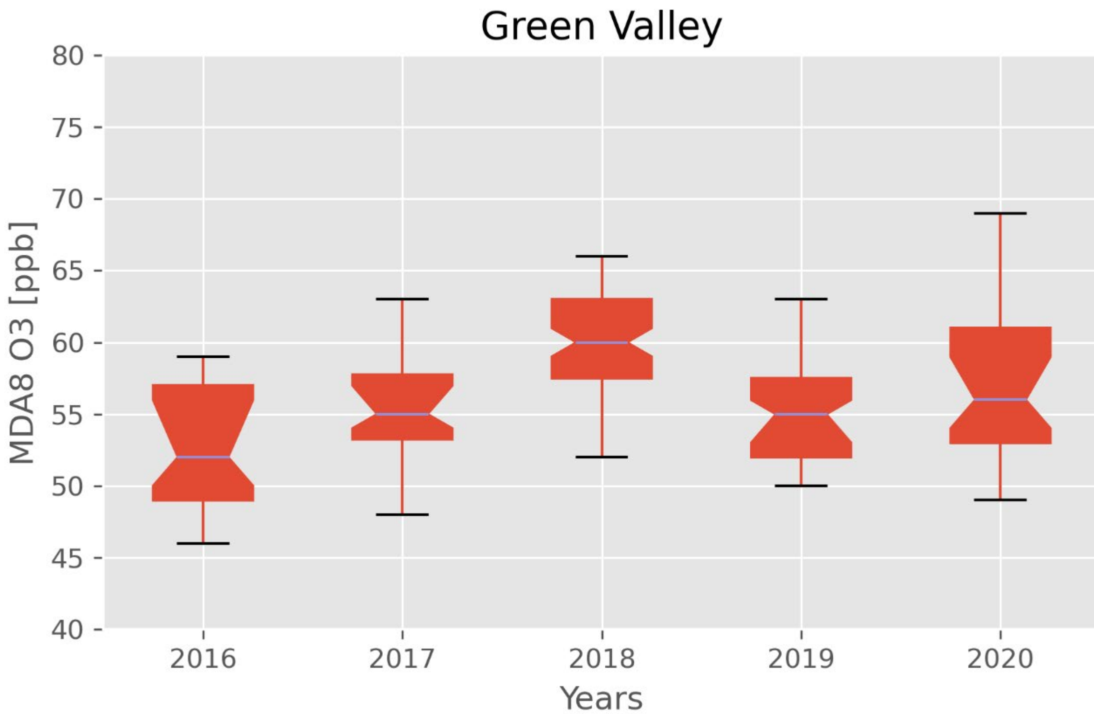


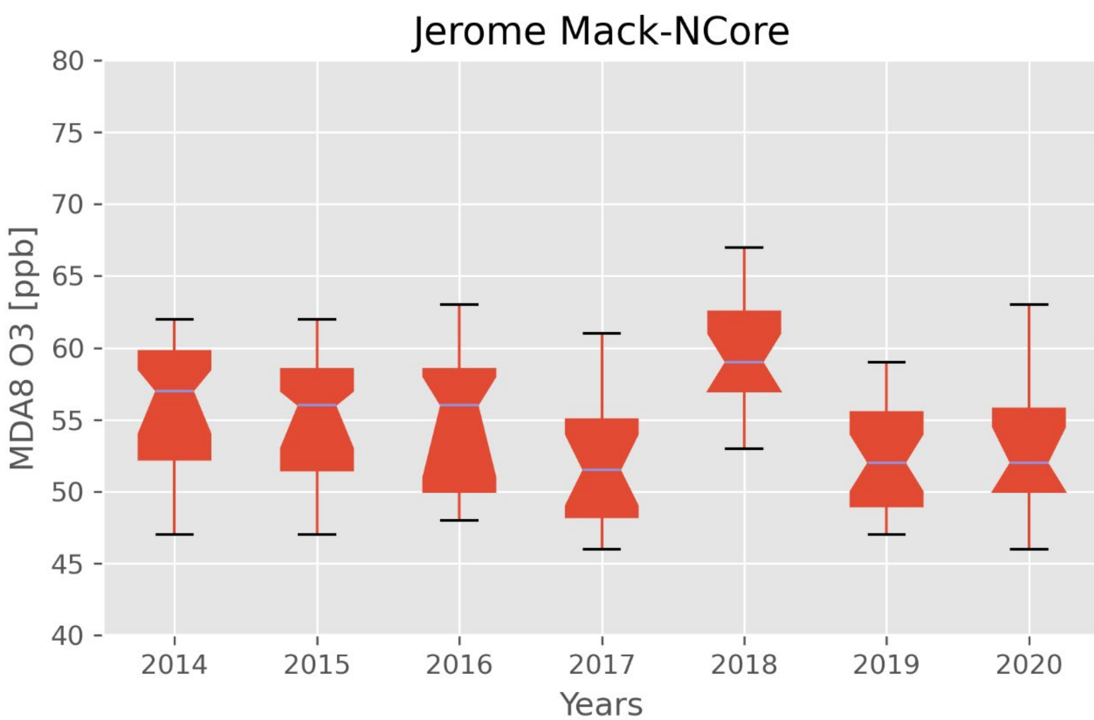
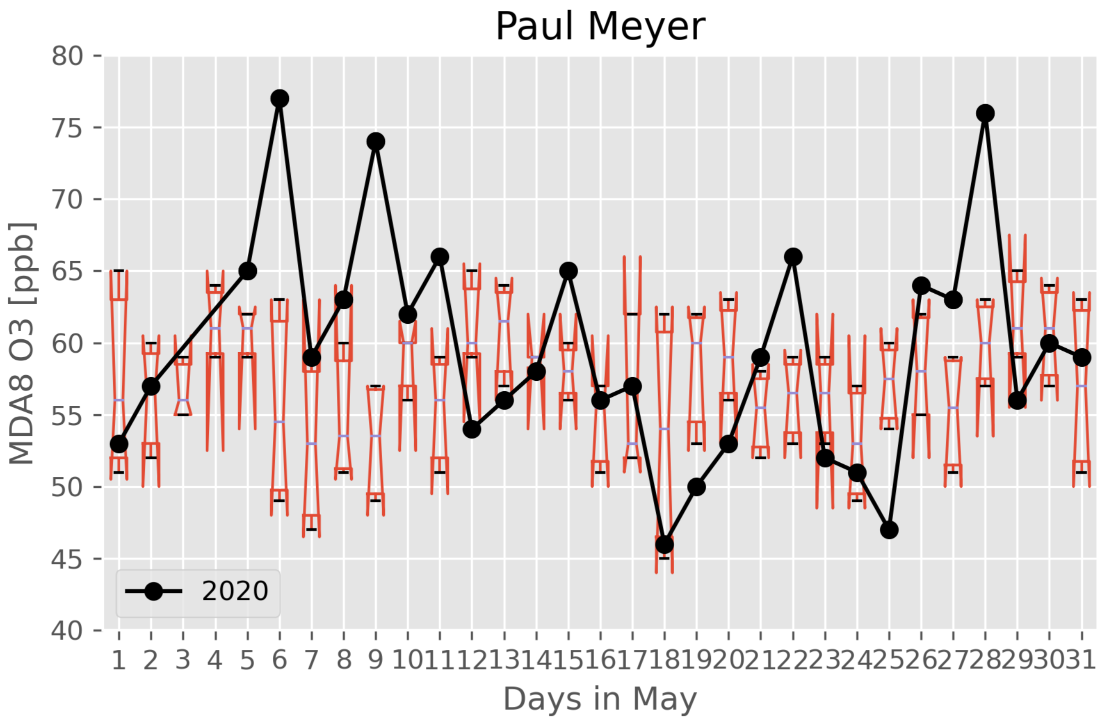
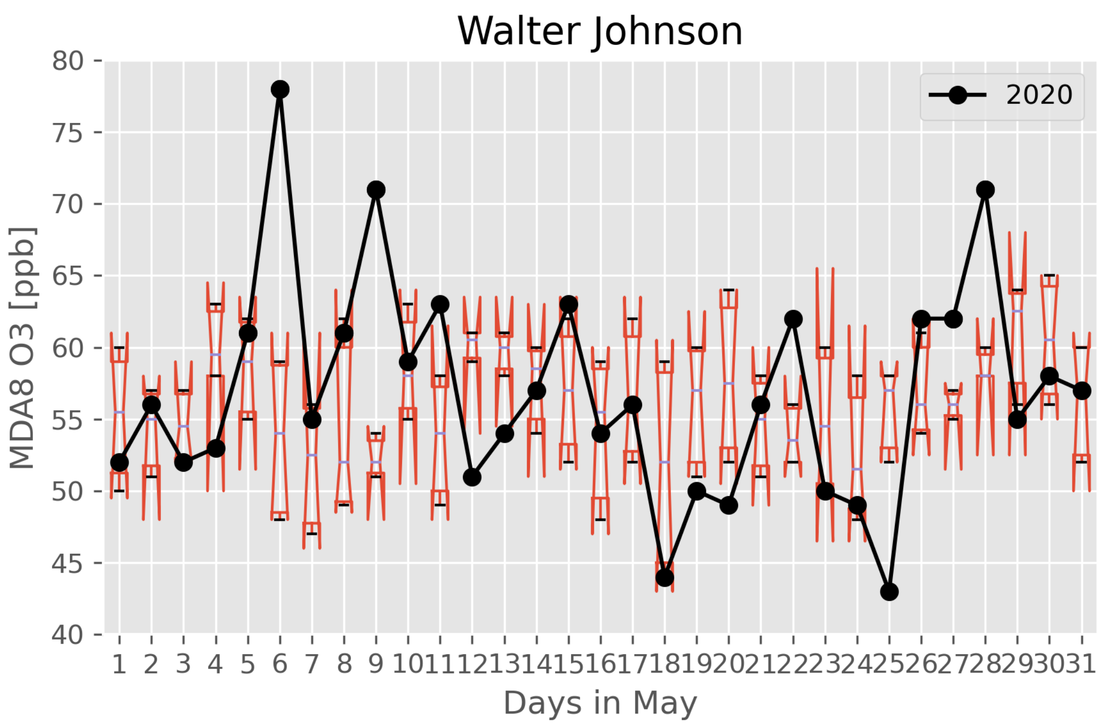
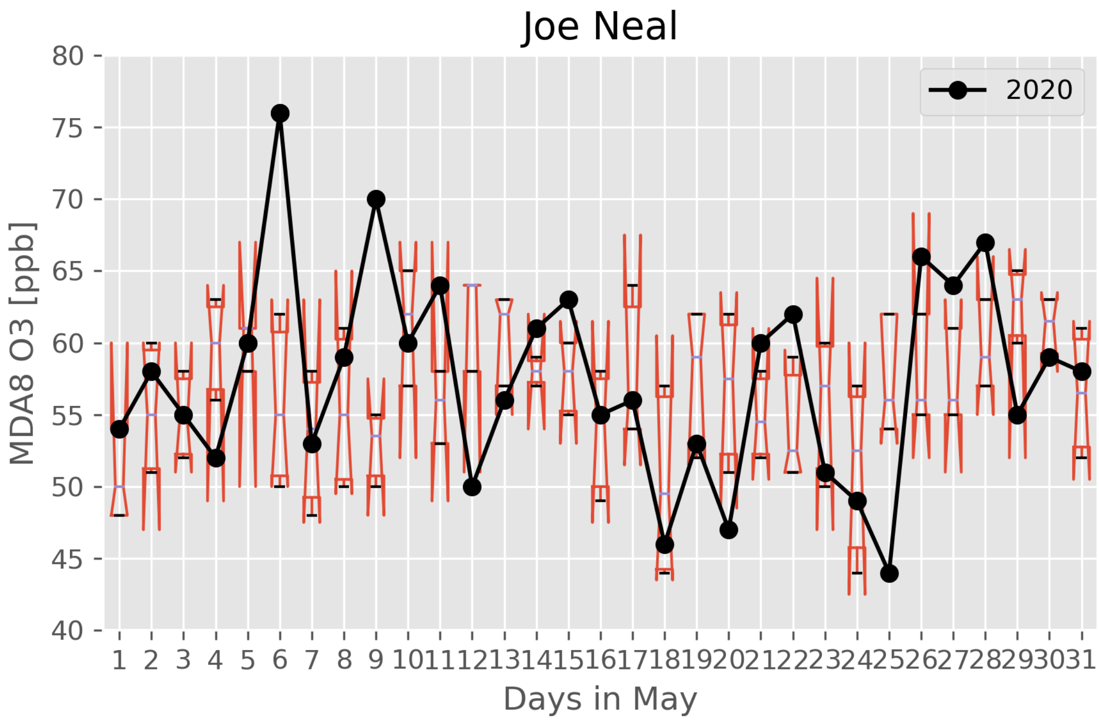


Figure G-2. Annual May distributions of MDA8 ozone at sites with EEs during May 2020. Notches denote 95th confidence interval of the median, boxes are 25th, 50th, and 75th percentiles, and whiskers are 5th and 95th percentiles.


Paul Meyer
MDA8 O3 [ppb]
Days in May
2020


Walter Johnson
MDA8 O3 [ppb]
Days in May
2020


Joe Neal
2020
MDA8 O3 [ppb]
Days in May
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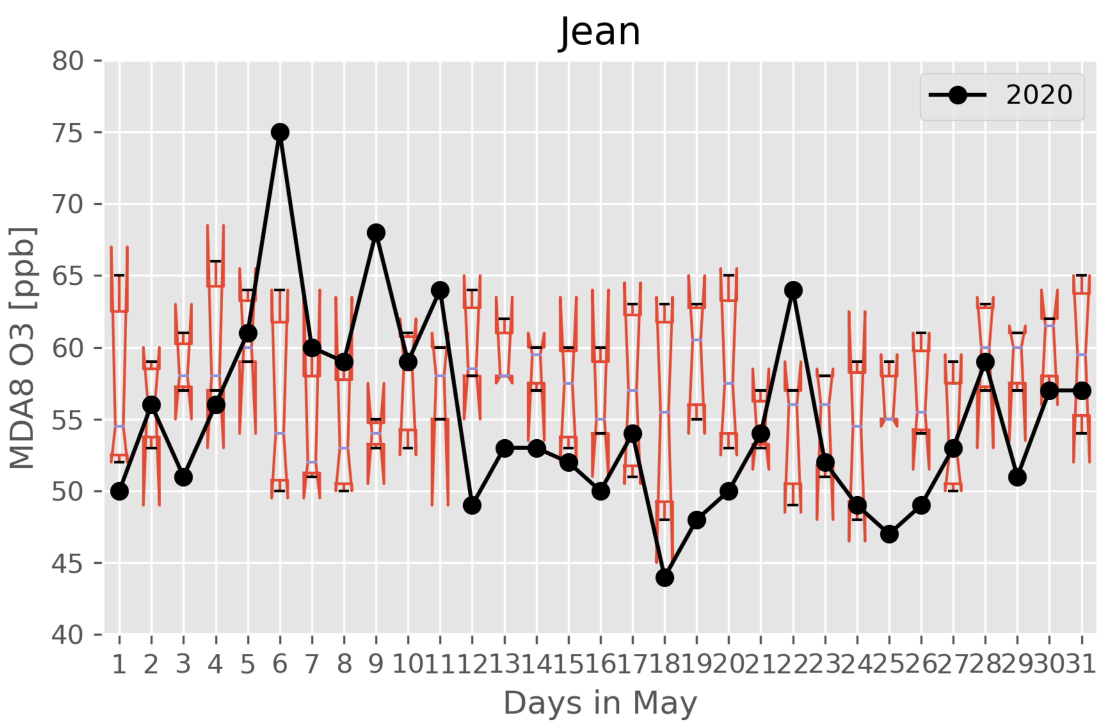
Jean
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MDA8 O3 [ppb]
Days in May
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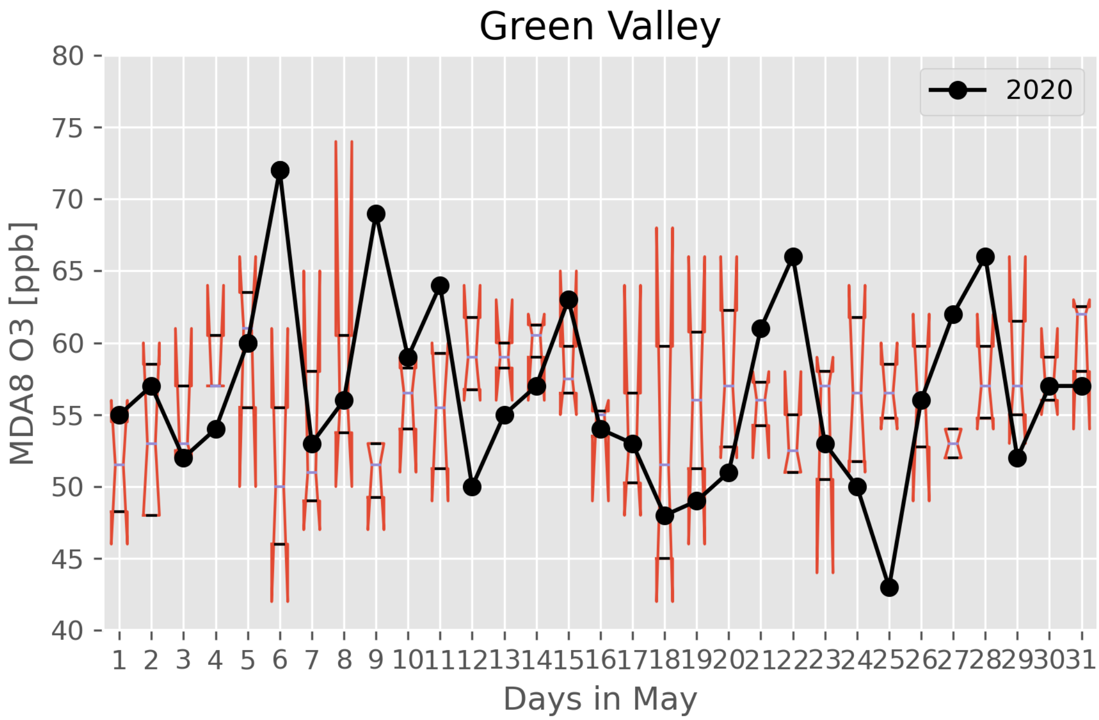

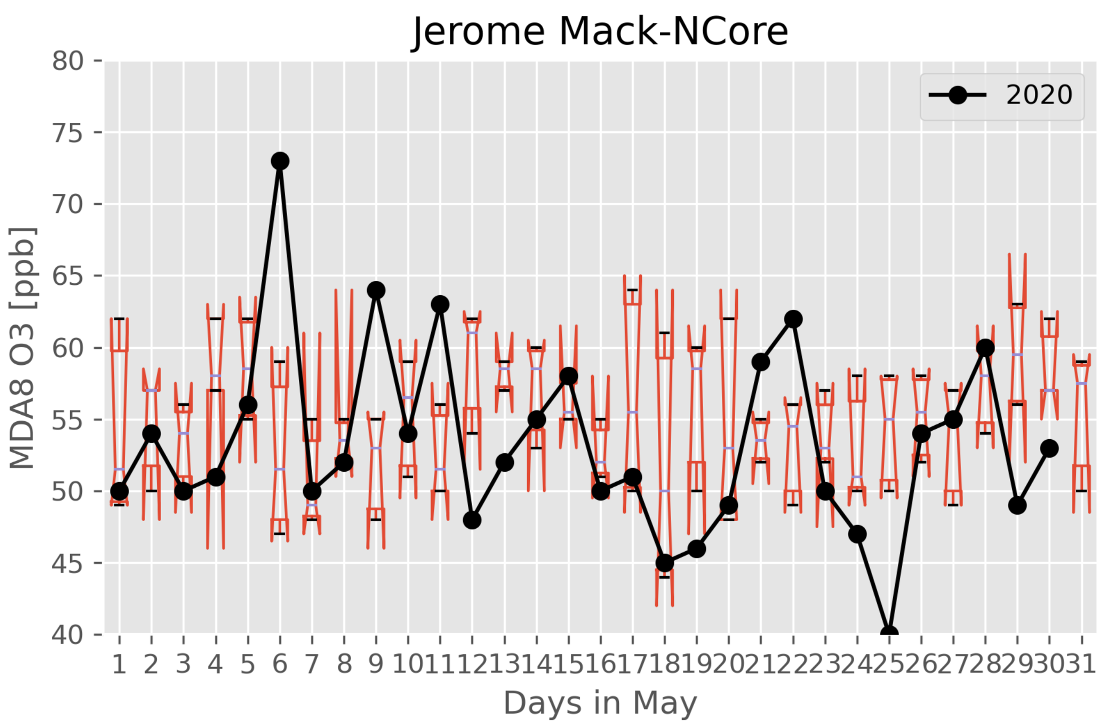

Figure G-3. Daily time series of 2014-2019 MDA8 ozone distributions and 2020 MDA8 ozone at each site with proposed EE during May 2020. Notches denote 95th confidence interval of the median, boxes are 25th, 50th, and 75th percentiles, and whiskers are 5th and 95th percentiles.

References

Clark County Department of Environment and Sustainability (2020) Revision to the Nevada State implementation plan for the 2015 ozone NAAQS: emissions inventory and emissions statement requirements. September. Available at https://files.clarkcountynv.gov/clarknv/Environmental%20Sustainability/SIP%20Related%20Documents/O3/20200901_2015_O3%20EI-ES_SIP_FINAL.pdf?t=1617690564073&t=1617690564073.

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Appendix H. Documentation of the Public Comment Process

To be updated once the public comment period has concluded.